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CONTENTS

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AGRICULTURAL ENGINEERING

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Tomatoes, Tanks, and Tomorrow

SPECTACULAR and significant as are the early results reported by Messrs. Gericke and Tavernetti in growing amazing yields of tomatoes under glass in electrically heated nutrient solutions, we hope that they can be guarded from exploitation by the type of journalism which delights perennially in finding the farmer superfluous and predicting that the human race is to be nourished by a tablet from the vest pocket, a concentrated creation of modern alchemy. Ignoring all the other factors of cost in producing crops under glass, a comparison of the electric energy consumption, at any conceivable rate, with the yield of tomatoes shows that we still are a long way from the point where the soup factory can add a glass porch and a transformer, and thereafter say goodbye to fields and farmers.

It would be most unfortunate, at a time when the consent of public opinion is being mobilized for a much-needed program of soil conservation, for the idea to get abroad that soil is something we presently can do without. Such a possibility is not so absurd as we may think; the yearning of the non-technical mind to believe the unbelievable is almost infinite when the magic name of electricity is invoked.

On the other hand, the electric people themselves will be first to compare the cost of heating cable with that of copper or other tubing, and cost of electric energy with that of heat from the regular greenhouse heating plant, and the accuracy of control by thermostatic switches with that of similarly controlled valves for steam or hot water. And all such individual tank-warming methods must compete with centrally heated systems in which all of the circulating medium is held within an appropriate temperature range.

Whatever the system employed, electric or otherwise, it seems obvious that the results already attained point the way to such increase of capacity for each square foot under glass, and of each cubic foot artificially heated, as to reduce sharply the overhead and overall costs of producing tomatoes under glass. Presumably some other crops will be found similarly responsive to this method of culture.

Though hothouse vegetables now are mainly epicurean luxuries, our steadily advancing knowledge and recognition of dietetic values should bring us presently to the point of studying the vitamin and mineral values that can be embodied in vegetables grown under intensive control. The nutrient solution would seem ideal for regulation of the mineral intake of plants, and for the economical use of fertilizer elements that otherwise would cost too much.

Rubber Rolls On

PUBLICATION in this issue of the paper by Samuelson, Hurlbut and Smith serves as a milepost in the steady progress of the pneumatic tire in agriculture. The very fact that colorful experiences, amazing comparisons with steel lugs, and pointed criticisms are lacking is evidence enough that the rubber tire has survived its probation and has become just one more item for routine engineering. We note with satisfaction that the present study takes the direction suggested some time ago in these columns, namely, an exploration of the factors controlling pneumatic tires as traction members, separated from the characteristics of the tractor on which they may be used.

Another evidence of real progress are the moves toward tire equipment interchangeable among sundry pieces of farm machinery. Active commercial promotion of a cut-down-and-change-over system comprises one of these moves. A rim band or felloe to be welded to the cutoff spokes of existing wheels, with a demountable rim, bring the advantages of rubber and of interchangeability to farmers without waiting for the design and purchase of factory-built interchangeability. If history repeats itself, this expedient will be valuable mainly as a demonstration project hastening the day of machinery designed for interchangeable pneumatic tires.

The other move, in the latter direction, has tangible support in the serious consideration being given the plan by the Tractor and Thresher Department of the Farm Equipment Institute. What type of interchangeability may evolve from their deliberations is something of which we have no advance hint, nor any desire to dictate. We venture to recall—merely for consideration on its possible merits—the suggestion some years ago in these columns of a complete tire, wheel, bearing, and inner-sleeve assembly, the inner sleeve to be adaptable to various diameters of rough axles by split cones of appropriate taper. It was suggested that this would reduce to a minimum the duplication of material and permit the employment of high-grade anti-friction bearings permanently adjusted, permanently lubricated, and permanently sealed against dirt and moisture.

To be weighed against these seeming advantages is the handicap of immobility when the tire, and with it the wheel, is in use on other equipment. The alternative construction—demountable rim and permanent wheel—would seem to afford a degree of mobility by using the felloe as a steel tire. Nevertheless, with the drawbar pull available from a modern rubber-tired tractor, this writer would be not too confident of moving a thresher over a typical farmstead soil if the thresher were supported only by a felloe of reasonable width, and of the reduced diameter remaining inside a low-pressure tire, rim, and lug clearance.

With lighter machines or implements this difficulty would be less, but that of ground clearance would remain. Plows might have to be designed with still higher lifts, and binders, combines, threshers, etc., might easily reach zero clearance with a little sinking of the small wheels into soft earth. Makers and users of the demountable-rim changeovers will render a real service to the industry at large by reporting promptly their experience as it bears on the relative significance of these points.—W.B.J.

Finance Favors Soil Conservation

"THE POPULATION of this country is still increasing, even though not so rapidly as in the past, and no doubt agriculture will gain with the other industries by a restoration of general prosperity. The arable land within our boundaries is practically occupied, and more is cultivated than should be. Genuine conservation of the national resources is a proper subject for consideration," says the monthly news letter of the National City Bank of New York, and it adds, "Moreover, Europe may return to larger-than-present importations of our farm products, and is more likely to do so if we reduce our costs, instead of artificially raising our prices."

While we may stretch a point to cite the dictum of this bank as the judgment of all finance, it at least is a viewpoint remote from agrarianism. The cautious restraint of its wording suggests mature deliberation and conservative thinking. Since engineering and finance do not always see eye to eye, their concurrence in this instance seems doubly significant.

While inclusion of the word "genuine" might imply criticism of methods, we take it to mean any and all procedures that are technically sound and economically feasible. And we note with satisfaction that the author chooses to say "national resources" rather than "agricultural resources." Certainly the mobility of population would make transitory the advantages to a part of the people in the course of a program so permanent as that of soil and water conservation. A productive, efficient agriculture resolves itself into low-cost living for consumers and profitable markets for non-agricultural products and services.

All of which tends to fortify our feeling that conservation programs should be planned and their costs allocated as fairly as possible according to the benefits to be conferred. A possible grouping might be: (a) direct benefits to the land operator; (b) temporary benefits to agriculture as a class or industry; (c) ultimate benefits to the nation. With these as guiding principles it will take the best of judgment to arrive at approximate equity. However, a broad approximation is better than no attempt at quantitative equity.

Simple as are the guiding principles, the administrative problem is bound to be complex. Both to avoid further complexities, and as an aid to straight thinking by the populace on the subject of conservation, it would seem wise to keep it so far as possible free from entanglement with other agricultural objectives, especially those of a less permanent nature. So classified, planned, and assessed, conservation will—we venture to guess—merit the continued support of finance as well as engineering.

The Flood Problem Goes to Town

ALMOST a didactic dispensation is the distribution of this spring's flood havoc. As we write this, there is yet time for the lower Mississippi valley to be flood-ridden, but at the moment the map of 1936 floods is a map of industrial America, excluding the Great Lakes-Mississippi River area. Through New England, Pennsylvania, and along the course of the Ohio River industry looms large; agriculture is relatively less important. In a way too cruel to be deemed providential, the people of these regions have had driven home to them—if they care to heed—the city's stake in soil and water conservation.

To be sure, they are concerned not with conservation as such, but in its counterpart, control. And by what may be another coincidence, the doctrine of flood control at the source is now discernible in the public prints. Whether control at the source can be more effective, or more economic for a given degree of control, is not a matter for popular discussion, but of patient engineering study.

In certain metropolitan newspapers we have seen the editorial opinion that farmers who locate in river bottoms have done so in the hope of easy earnings from fertile soils; that they should take the risks with the gains and not look to government for succor in time of deluge. Sometimes the hint is added that such places belong more logically to the duck hunter than to the farmer. These editors, however, fall a bit short of the logical conclusion, namely, that duck hunters have the same right as farmers to acquire title and pay taxes on the bottom lands. Nor do they proceed to the more momentous point that cities have been located along rivers for equally mercenary reasons, and that their dwellers should equally bear their own risks without looking to public authority for flood relief.

We prefer the more merciful view that neither farmer nor townsman should be held too closely to the penalties for his misjudgment and his misdeeds—especially when the deeds and judgments are the heritage of several generations. Undeniably forest removal, swamp drainage, clean tillage, road construction, etc., have created much of the flood problem for the city, but it has also shared in their benefits. So interwoven are the blames and benefits, past and future, that a united attack on the common problem, as a regional or national problem, seems both equitable and logical.

While we assert that the prescription of "control at the source" is exclusively an engineering matter, we also believe it desirable that popular opinion should be "sold" on the idea of coordinated measures for flood control and soil conservation so far as practicable. It should not take an engineer to grasp the principle that a broadly correlated program to serve several concurrent purposes is likely to be more effective, more economical, and more equitable in the relation of costs to benefits.

The Joint Committee Approach

THE National Joint Committee on Fertilizer Application and its program, described elsewhere in this issue, provides a beautiful example of a cooperative set-up for studying a mutual problem covering several separate fields of agriculture.

Several organizations interested, each from its own special angle, in a particular problem or accomplishment, can direct their best qualified men and a wealth of experience into a joint effort with a reasonable assurance of rapid progress. The breadth of viewpoint represented in a joint committee minimizes "blind-alley" undertakings. It assures proper attention to all important considerations. It mobilizes and directs application of the necessary combination of highly specialized knowledge and technical skill.

Agricultural engineers may well consider the advantages of this method of approach in the study of other problems.

Heating of Liquid Culture Media for Tomato Production

By W. F. Gericke and J. R. Tavernetti

SEVERAL YEARS AGO, one of the authors (Gericke) initiated investigations to determine the feasibility of crop production without soil by application of a principle long known to plant physiology, namely, the culture of plants in aqueous nutrient solutions. The feasibility of the proposition was demonstrated by growing a fairly large array of field, vegetable, and floral crops in large shallow basins of water supplied with the nutrient elements that fertile soils render available to vegetation. Successful culture during the season usually considered as appropriate for such crops, suggested experimentation on crop production out of season by heating the nutrient solution. During the past year an experiment was conducted by Gericke in cooperation with the California CREA on the growing of tomatoes in heated liquid media. This paper describes the equipment used in this experiment with a brief statement of the result. The general method of growing plants in liquid media is still in the experimental stage and the details can not be given until further experiments are conducted.

The experiment was conducted in an unheated greenhouse with the equipment shown in Fig. 1. This equipment consisted of sheet metal tanks each 2½ feet wide, 10 feet long, and 8 inches deep, over which were wooden frames containing a wire screen that was held just above the top of the tanks. Two to three inches of excelsior and sawdust were placed on the screen to provide support for the plants. In each of the heated tanks there was a thermostat and 60 feet of soil-heating cable having a connected load of 400 watts. The only insulation on the tanks was the excelsior and sawdust over the top and the 1-inch boards of the frame around the sides.

Five tanks were used, four heated and one control. The solution in two of the heated tanks was maintained between 75 and 80 degrees (Fahrenheit) for the first six weeks, after which it was increased 5 degrees, to a range of 80 to 85 degrees. The solution temperature in the other two heated tanks was maintained between 65 and 70 degrees for the first six weeks and then increased 5 degrees, to a range of 70 to 75 degrees. The temperature of the solution in the check tank ranged between 55 and 65 degrees, depending upon the air temperature in the greenhouse.

Authors: Respectively, associate plant physiologist, and associate in agricultural engineering (Assoc. Mem. ASAE), University of California.

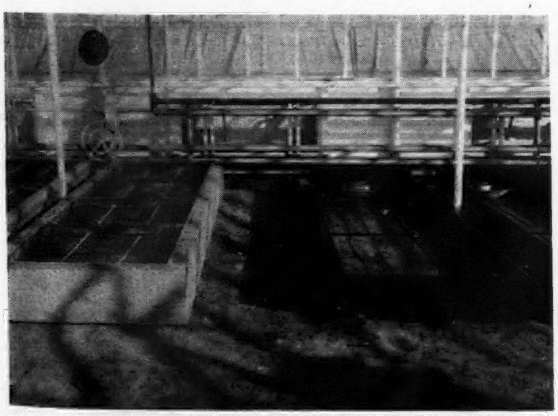


FIG. 1 EQUIPMENT USED IN THE EXPERIMENT. THE TANKS ARE 10 FEET LONG, 2.5 FEET WIDE, AND 8 INCHES DEEP. VISIBLE IN THE OPEN TANK ARE THE SOIL-HEATING CABLE AND A BOTTLE OF NUTRIENT SALTS

Two varieties of English greenhouse tomatoes, Sutton's Best of All and Sutton's Majestic, were grown. The plants were started in soil and transplanted into the tanks on December 19, 1934, as three-weeks-old seedlings. Two rows of ten plants each were planted in each tank making one plant to about 1¼ square feet of water surface.

The tanks were filled with water to within one inch of the top and each tank received one "fertilizing unit"—a bottle containing one pound of nutrient salts. The "fertilizing units" were so constructed that the salts were gradually diffused into the water. New units were supplied as required, seven being the total used per tank for the twelve months' period.

Table 1 shows the electrical energy required to heat the solutions during the first six months of the experiment. The energy required to maintain an 80 to 85-degree temperature was nearly double that required for 70 to 75 degrees. No corrosive action from the salts used in the culture media was observable on the cable after one year's continual use.

Table 2 gives the quantity of tomatoes harvested from each of the tanks. The growth with the heated media was considerably faster and more vigorous than in the unheated as shown in Figs. 2 and 3. The difference became somewhat less as the season advanced and the temperature of the unheated media increased. There was practically no difference in the rate of growth or the yield of fruit between the 70 to 75 degrees and the 80 to 85 degrees basins. The fruit in the heated basins began to ripen during the latter part of April and the harvest continued until December 19, 1935, when the experiment was discontinued. The

TABLE 1. ELECTRICAL ENERGY CONSUMED IN HEATING THE NUTRIENT SOLUTION TO VARIOUS TEMPERATURES AND AVERAGE RANGE IN AIR TEMPERATURES IN THE GREENHOUSE

Period	Days	Kw-hr consumed in tanks 1 and 2*	Kw-hr consumed in tanks 3 and 4†	Average range in air temperatures, deg F
Dec. 19-Jan. 5	17	157	94	51-79
Jan. 5-Feb. 1	27	211	62	58-84
Feb. 1-Mar. 4	31	302	166	52-78
Mar. 4-Apr. 1	28	301	188	50-83
Apr. 1-May 2	31	292	157	55-84
May 2-June 5	34	307	188	
Total	168	1570	855	

*Solution temperature—Dec. 19 to Feb. 1, 75 to 80 deg F; Feb. 1 to June 5, 80 to 85 deg.

†Solution temperature—Dec. 19 to Feb. 1, 65 to 70 deg F; Feb. 1 to June 5, 70 to 75 deg.

FIG. 2 (LEFT) VIEW OF THREE-MONTHS-OLD TOMATOES IN THE 80 TO 85-DEGREE TANKS. FIG. 3 (RIGHT) THREE-MONTHS-OLD TOMATOES IN THE UNHEATED CONTROL TANK

TABLE 2. YIELD OF RIPE TOMATOES PER TANK OF 25 SQUARE FEET WATER SURFACE ON PLANTS GROWN 12 MONTHS

Tanks	Temperature of solution, deg F	Pounds of tomatoes harvested	Variety
1	70-75	297.4	Sutton's Best of All
2	70-75	301.3	Sutton's Majestic
3	80-85	273.4	Sutton's Best of All
4	80-85	352.2	Sutton's Majestic
5	55-65	51.0*	(One row of each of the varieties.)

*The check tank was discontinued when the plants were 7½ months old; the yield would have been greater if the plants had been allowed to grow the full test period.

major portion of the fruit, however, was harvested within the first eight months. The fruit in the unheated basins began to ripen about six weeks later than in the heated.

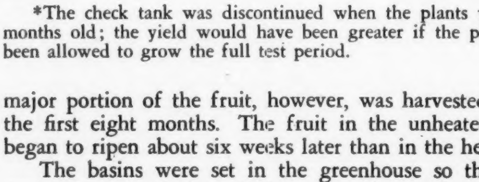
The basins were set in the greenhouse so that there was only about 6 feet of clearance between the roof and the seedbed at one end and about 16 feet at the other end. When the plants were about six months old, those under the lower part of the roof were cramped and the yield curtailed. When the experiment was concluded at the end of one year, those plants having room to grow attained a length of 25 feet and bore fruit over the entire length.

CONCLUSIONS

1 The exceptionally large yields of tomatoes, which were of high quality according to the opinions expressed in the market on which they were sold, is evidence that the heating of liquid culture media can be employed as a means of growing tomatoes out of season.

2 By heating the culture solution and by providing proper shelter for the plants, tomatoes can be grown as an all-year crop that will yield ripe fruit for 8 to 9 months.

3 The potential yield of tomatoes from a unit area of properly prepared nutrient solution is many fold greater than that of soil because of the greater density of stand, taller plants bearing fruit the entire length of the stalks and the longer growing period. *(Continued on page 184)*



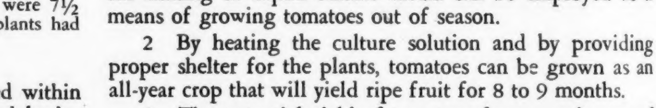


FIG. 4 (LEFT) TOMATOES IN THE 80 TO 85-DEGREE BASIN AT AGE OF FOUR MONTHS AND THREE WEEKS, SHOWING HEAVY SET OF TOMATOES ON LOWER PART OF PLANTS. FIG. 5 (RIGHT) TOMATOES IN HEATED BASINS AT SIX MONTHS. FIVE POUNDS OF TOMATOES PER SQUARE FOOT OF WATER SURFACE HAD ALREADY BEEN HARVESTED

The Effect of Tractor Tire Size on Drawbar Pull and Travel Reduction

By Marvin J. Samuelson, Lloyd W. Hurlbut and C. W. Smith

THE Agricultural Engineering Department of the University of Nebraska was enabled to make this study with the assistance and cooperation of two companies. The Minneapolis-Moline Power Implement Company furnished a JT tractor and wheel equipment which permitted five different pneumatic tire sizes to be mounted on the one tractor. The Goodyear Tire and Rubber Company furnished the 5 sizes of tires and tubes.

Data was secured from three sources to be referred to hereafter as (1) the Nebraska tractor testing course, (2) the English farm, and (3) the Hoffman farm.

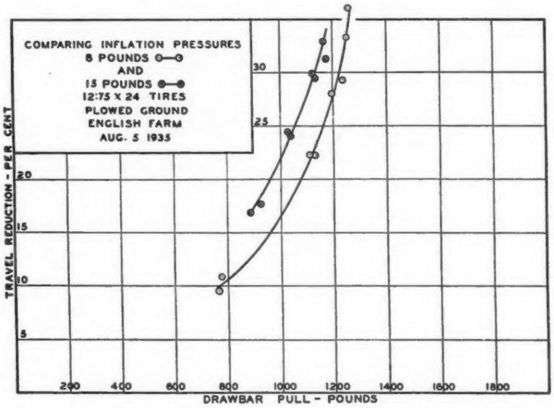
The tractor testing course is that track on which all official tractor testing drawbar work is done.

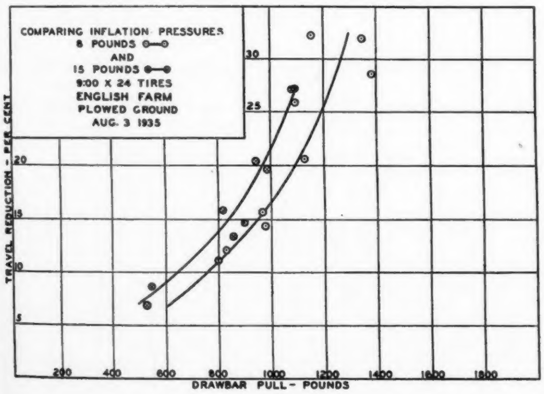
The English farm is 5 miles northwest of Lincoln. The field used is flat and almost perfectly level. It had previously been in wheat and the stubble was freshly plowed to a depth of 6 inches in preparation for these tests. The soil was dry and somewhat lumpy.

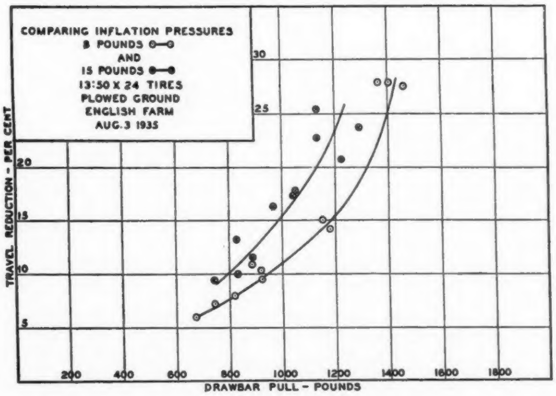
The Hoffman farm is 6 miles northeast of Lincoln. The field used is flat bottom ground. Wheat had been harvested from this ground and the stubble freshly plowed in preparation for fall wheat. The soil was in better tilth than that on the English farm.

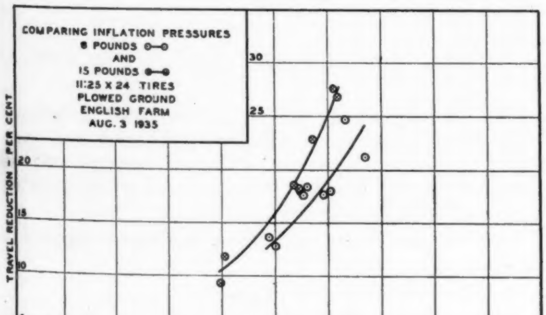
Presented before the Power and Machinery Division of the American Society of Agricultural Engineers at Chicago, December 2, 1935.

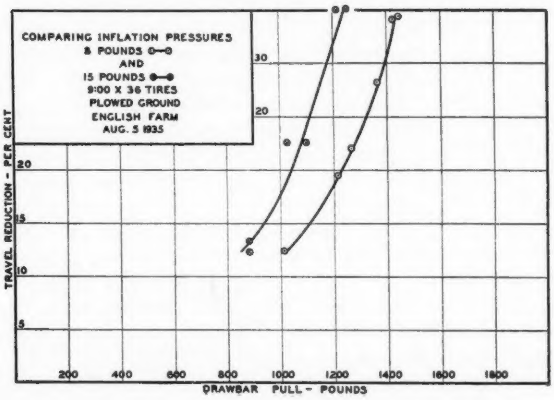
Authors: Respectively, student (Student Mem. ASAE), assistant, and professor (Mem. ASAE), department of agricultural engineering, University of Nebraska.



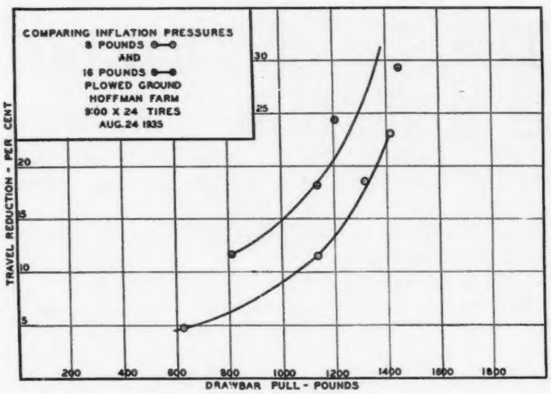


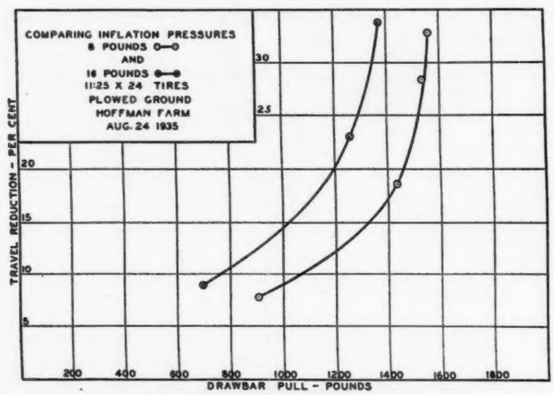






THE FIVE CHARTS IN THIS GROUP COMPARE INFLATION PRESSURES ON ALL TIRES ON THE ENGLISH FARM





THE FIVE CHARTS IN THIS GROUP COMPARE INFLATION PRESSURES ON ALL TIRES ON THE HOFFMAN FARM

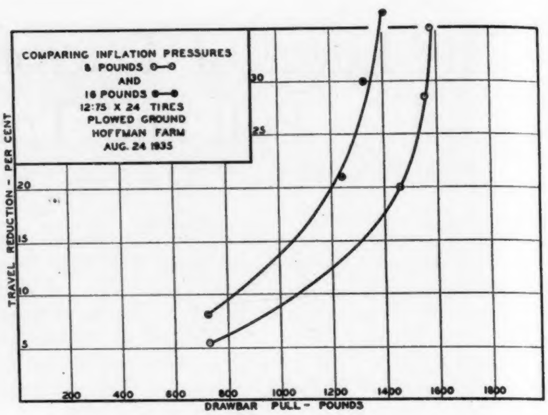
The drawbar loading equipment was a Douglas truck on which had been mounted a generator and controls for regulating the loads.

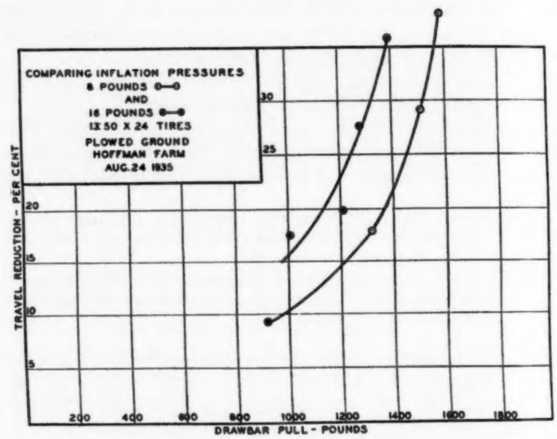
Two tire inflation pressures were used throughout: 8 pounds and 16 pounds, with the exception of tests run on the English farm. There 8 pounds and 15 pounds were used. A mercury manometer was used for measuring tire pressures.

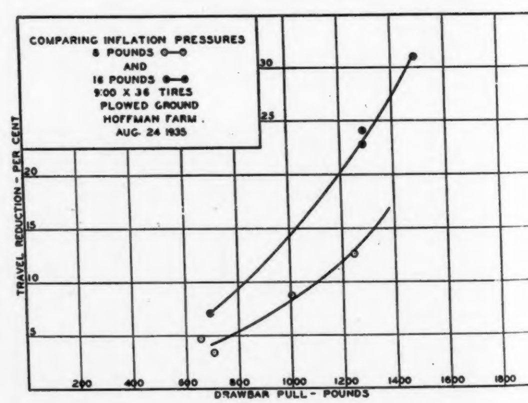
While testing on the plowed ground, the tractor never followed the same tracks twice.

The tests were made in rapid succession, the longest time elapsing between the beginning and the end of a series occurred on the English farm when a series incompleted Saturday night was finished Monday. No rain or other climatic condition arose to throw doubt on the comparableness of results.

The wheels furnished with the tractor were cast iron and would take demountable rims. Their weight was enough greater than the spoked wheels commonly used to make the equivalent of approximately two cast iron weights. Preliminary tests were made on the tractor testing course in which no attempt was made to keep either hitch height or rear end weight constant. Later the rear end of the tractor was weighed with each wheel equipment and sand bags added or removed from a box mounted on the fenders directly above the rear axle to keep the rear static weight of the tractor constant with all tires. A drawbar hitch was constructed which made it possible to keep the drawbar height at 8 inches.







As has been stated, 5 tire sizes were used, 2 inflation pressures, 4 loads, and 3 locations. This indicated 5x2x 4x3 = 120 trials if plans had worked perfectly and no duplications were needed. Some tests were cut short on the tractor testing course due to rain.

The results of this work are being shown under five divisions:

1 Comparing inflation pressures
2 Comparing all tires at constant inflation pressure
3 Comparing effective wheel diameters
4 Comparing tire cross sections
5 Comparing all tires for horsepower in one gear.

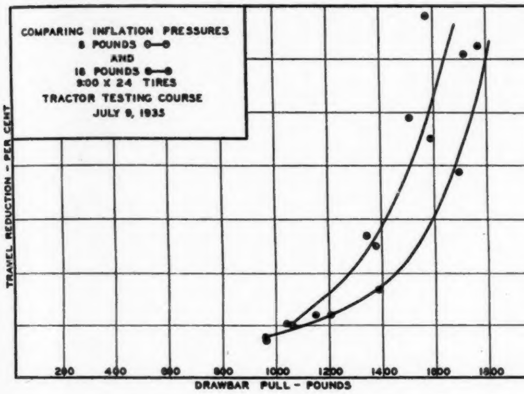
COMPARING INFLATION PRESSURES

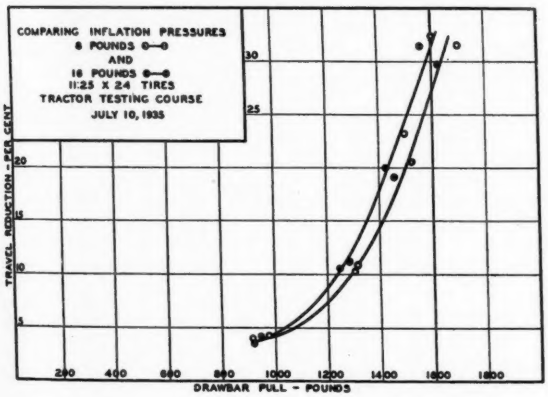
It was the aim at the beginning of the work to run all tests at two inflation pressures, 8 and 16 pounds. The mercury manometer was broken during the tests. It was repaired, and by error, used at 15 pounds instead of 16 pounds for the work on the English farm. This variation of one pound is less than the variation experienced with some commercial tire gauges and is not significant so far as this report is concerned. A series of 18 charts accompanying this report show that a gain in drawbar pull on plowed ground is consistently made when the tire inflation pressure is dropped from 16 to 8 pounds. They also show that a loss in drawbar pull on the tractor testing course is consistent when the pressure is dropped from 16 to 8 pounds. The drawbar pulls at 16 per cent travel reduction have been tabulated in Table 1. *(Continued on page 148)*

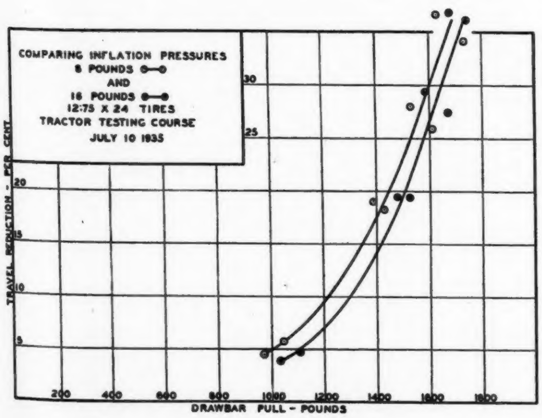
TABLE 1 DRAWBAR PULL AT 16 PER CENT TRAVEL REDUCTION

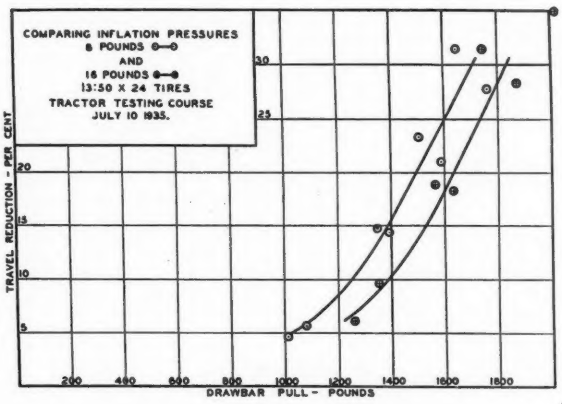
	Tractor Testing Course Variable weight and hitch, July 9, 10 and 11				Tractor Testing Course Constant weight and hitch, August 19			
Tire size	8 lb	16 lb	diff	Per cent diff	8 lb	16 lb	diff	Per cent diff
9.00x24	1440	1610	—170	—10.6	1420	1490	— 70	— 4.7
11.25x24	1370	1430	— 60	— 4.2	1400	1500	—100	— 6.7
12.75x24	1365	1440	— 75	— 5.2				
13.50x24	1410	1550	—140	— 9.0				
9.00x36	1640	1915	—275	—14.4	1480	1650	—170	—10.3
Average				— 8.7				— 7.2

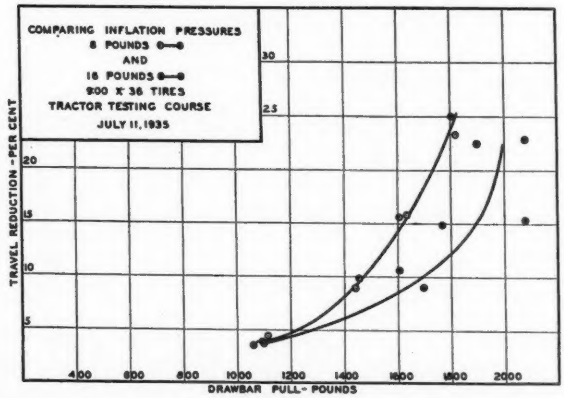
	English Farm, plowed ground, August 3 and 5				Hoffman Farm, plowed ground, August 24			
Tire size	8 lb	16 lb	diff	Per cent diff	8 lb	16 lb	diff	Per cent diff
9.00x24	985	870	+115	+13.2	1275	1050	+225	+21.4
11.25x24	1100	1005	+ 95	+ 9.5	1360	1060	+300	+28.3
12.75x24	990	870	+120	+13.8	1350	1085	+265	+24.5
13.50x24	1225	1025	+200	+19.5	1260	1010	+250	+24.8
9.00x36	1135	960	+175	+18.2	1360	1060	+300	+28.3
Averages				+14.8				+25.5



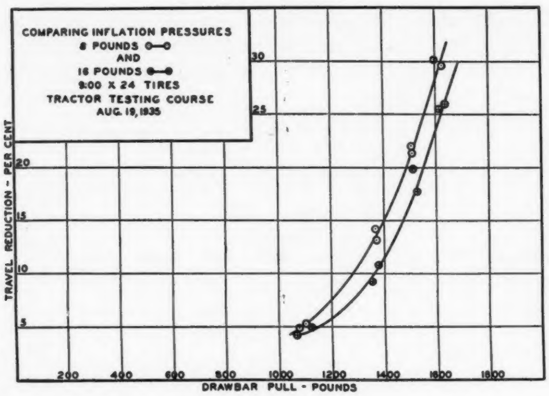


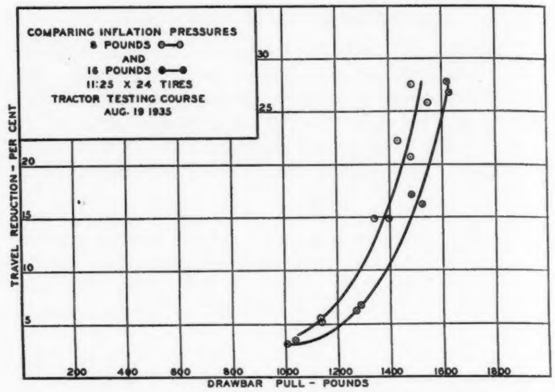




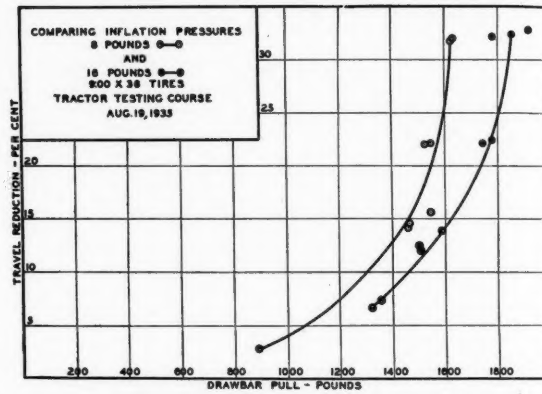


THE FIVE CHARTS IN THIS GROUP COMPARE INFLATION PRESSURES ON ALL TIRES ON THE TRACTOR TESTING COURSE IN JULY

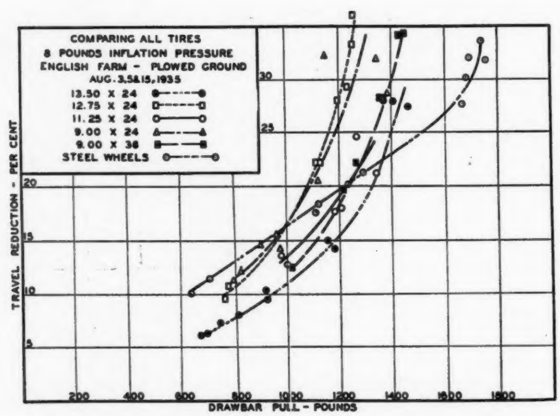


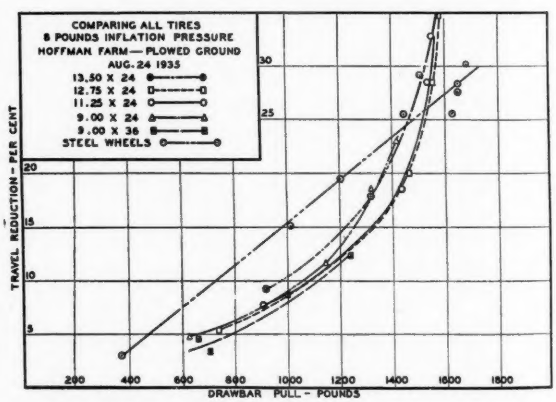


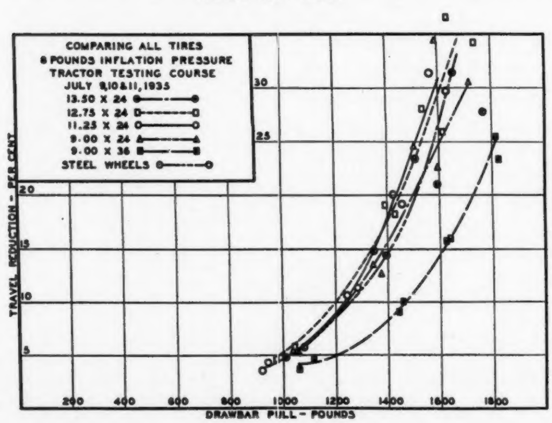
THE TWO CHARTS ABOVE AND ONE ON THE RIGHT COMPARE INFLATION PRESSURES ON THREE TIRES ON THE TRACTOR TESTING COURSE IN AUGUST

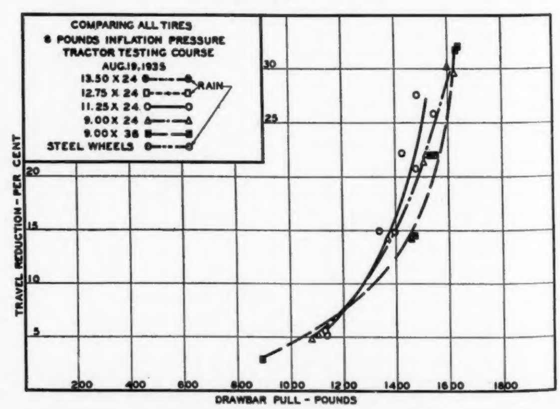


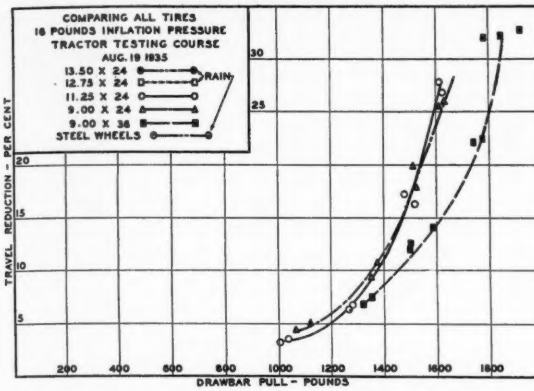
THE FOUR CHARTS AT THE BOTTOM OF THIS PAGE COMPARE ALL TIRES AT 8 POUNDS INFLATION PRESSURE

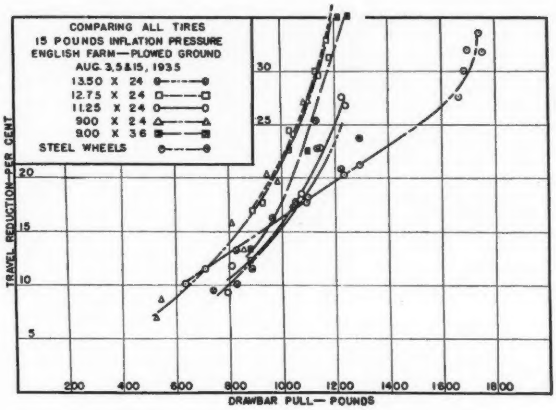


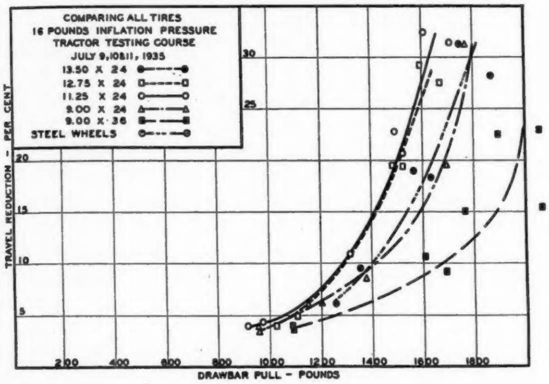


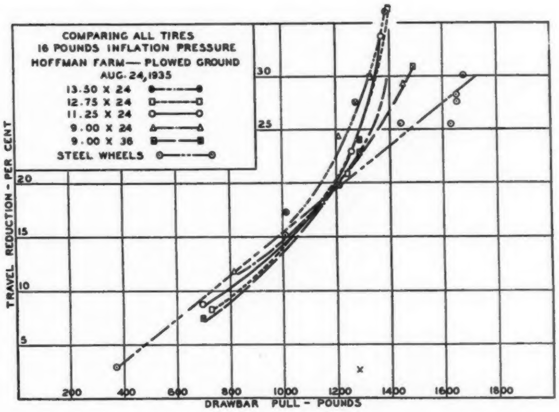


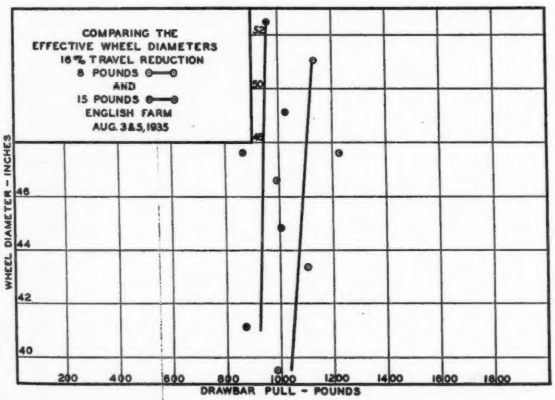






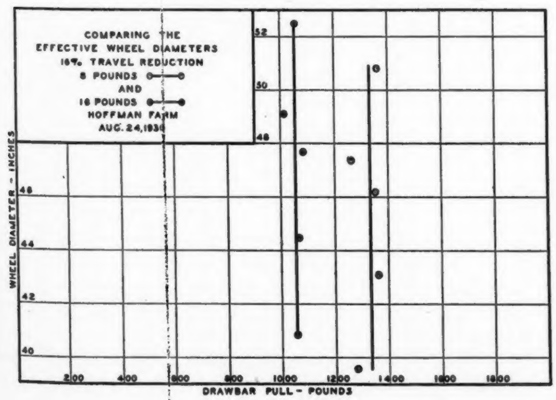






THE FOUR CHARTS AT THE TOP OF THIS PAGE COMPARE ALL TIRES AT 16 POUNDS INFLATION PRESSURE

THE CHART ON THE LEFT AND TWO CHARTS BELOW COMPARE EFFECTIVE WHEEL DIAMETERS



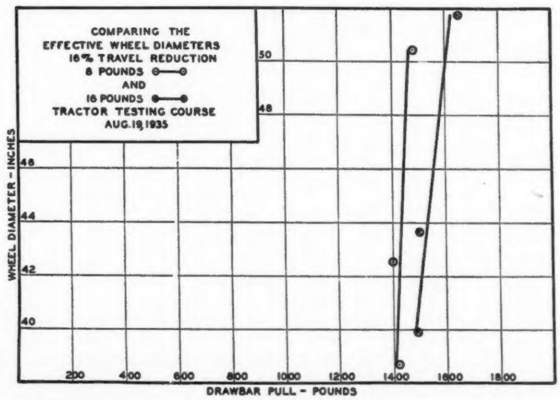


TABLE 2 RANKING TIRES BY DRAWBAR PULL AT 16 PER CENT TRAVEL REDUCTION

	Tire pressure, lb.	9.00x24	Ranking	11.25x24	Ranking	12.75x24	Ranking	13.50x24	Ranking	9.00x36	Ranking
Tractor Testing Course,	8	1440	2	1370	4	1365	5	1410	3	1640	1
8/9, 10 and 11/35	16	1610	2	1430	5	1440	4	1550	3	1915	1
Tractor Testing Course,	8	1420	2	1400	3					1480	1
8/19/35	16	1490	3	1500	2					1650	1
English Farm,	8	985	5	1100	3	990	4	1225	1	1135	2
8/3 and 5/35	16	870	4	1005	2	870	4	1025	1	960	3
Hoffman Farm,	8	1275	3	1360	1	1350	2	1260	4	1360	1
8/24/35	16	1050	3	1060	2	1085	1	1010	4	1060	2

TABLE 3 RANKING TIRES BY DRAWBAR PULL AT 16 PER CENT TRAVEL REDUCTION*

Tires	Times first	Times second	Times third	Times fourth	Times fifth
9:00x36	3	2	1		
13.50x24	2		2	2	
12.75x24	1	1		3	1
11.25x24	1	2	1	1	1
9.00x24		2	2	1	1

*Data taken on the tractor testing course in August was not used for this ranking because rain caused the 12.75x24 and 13.50x24 tires to be omitted.

(Continued from page 145) The drawbar pull at 16 pounds inflation pressure has been used as a base from which to compute gains and losses in percentage.

Putting these results in percentages these data show that by changing the inflation pressure from 16 to 8 pounds on the tractor testing course, a loss of 8.7 per cent in traction was experienced in July and 7.2 per cent in August, while on one plowed field a gain of 14.8 per cent in traction was made and on another plowed field a gain of 25.5 per cent in traction was secured. The tractor testing course was dusty on top with a hard base.

COMPARING ALL TIRES AT CONSTANT INFLATION PRESSURE

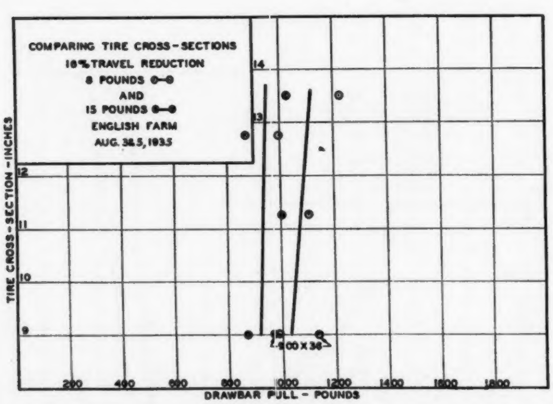
Eight figures are shown as a basis for this portion of the study. From these, Tables 2 and 3 have been made showing the rank of each tire in drawbar pull at 16 per cent travel reduction. Where the rank of two tires was the same, they were both given the same ranking number. These results and this classification should not be taken too seriously, because, in several instances, a relatively small difference in drawbar pull has caused one tire to rank ahead of another. One thing apparent is the favorable position of the 9:00x36 tires. Of the others little can be said.

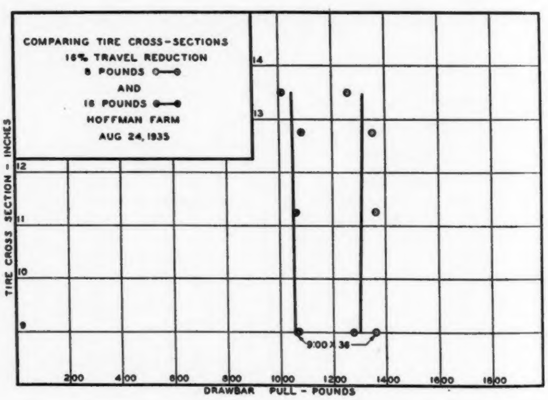
COMPARING EFFECTIVE WHEEL DIAMETERS

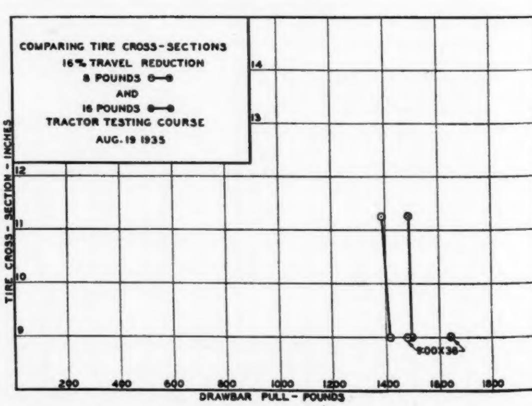
Three of the accompanying figures are given to show results when put on the basis of effective wheel diameters. An examination of these figures shows drawbar pull to be nearly independent of wheel diameter for the conditions of these tests.

COMPARING TIRE CROSS SECTIONS

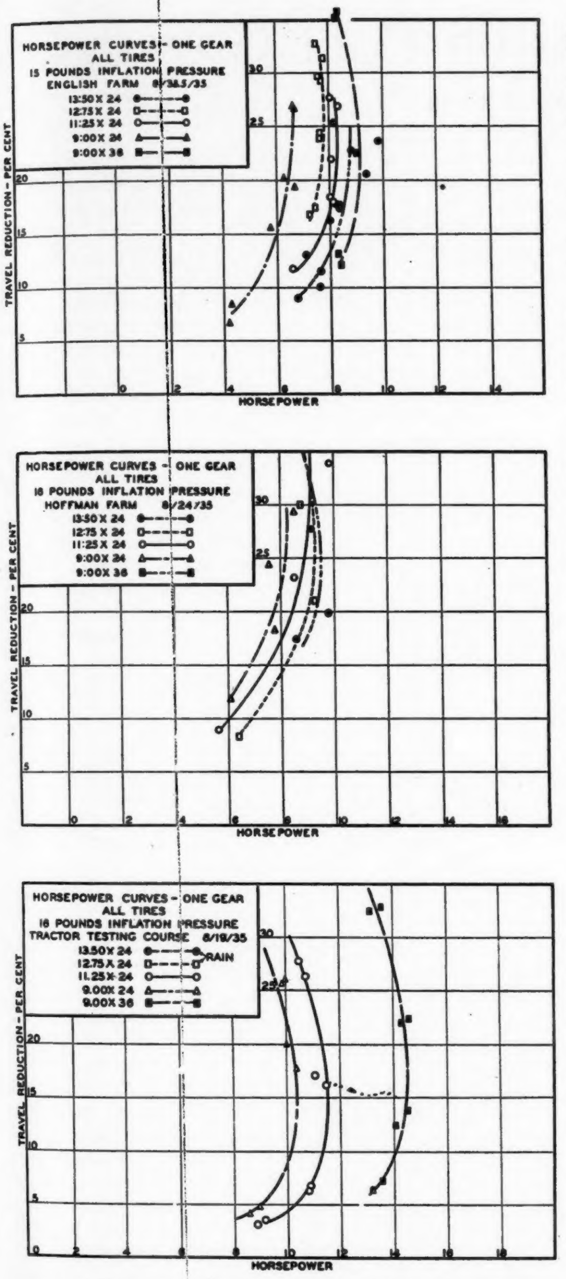
Three figures are shown, one for each location at which tests were made to show the effect of tire cross section. The data indicate that tire cross section alone had relatively little to do with drawbar pull under the conditions in which these tests were made.







THE THREE CHARTS IN THIS GROUP COMPARE TIRE CROSS SECTIONS



THE THREE CHARTS IN THIS GROUP COMPARE HORSEPOWER DEVELOPED

COMPARING ALL TIRES FOR HORSEPOWER IN ONE GEAR

The gear used was third, but this tractor had five gears, so the rate of travel was relatively slow for rubber tires. Since the drawbar pull is largely independent of the tire size and effective wheel diameter, it can readily be seen that the developed horsepower will be great for the larger effective wheel diameters. This is shown rather consistently by the graphs. Three charts show horsepower versus travel reduction. These are presented largely for their general interest. The chart for the tractor testing course confirms previous data in that 16 per cent travel reduction with pneumatic tires gives maximum horsepower. A somewhat higher percentage of travel reduction can be tolerated on plowed ground and a slight gain in horsepower secured thereby.

Most tractors up to the present time have been designed to use steel wheels. The use of pneumatic tires has meant, in most instances, a change from the steel wheels to the rubber tires. The question naturally arises in this connection, which tire will be the best? This *best* tire is usually thought of as the one which will give the greatest traction.

Tire sizes vary in cross section, in tread, and in diameter. These tests were made in an effort to determine the effect of cross section on a tire's tractive ability. Incidentally, some relations are noted relative to effective tire diameter and also to inflation pressures. But the effect of cross section was the primary aim. It has previously been determined that traction can be increased by adding weight to the traction wheels. Therefore, this effect was eliminated by keeping the weight on the drivers constant. A given weight is what a buyer gets in the purchase of any tractor. Taking this weight, which tire will give with it the most traction?

These data indicate that a change in tire cross-section did not affect traction.

The irregularity of the plotted points in some instances with reference to the curves should perhaps be attributed to the difficulty of exactly duplicating field conditions and not to inherent differences in the tires being compared.

On the figure comparing all tires at 16 pounds inflation pressure on the Hoffman farm, and "x" shows the drawbar pull of the tractor and also its travel reduction at rated load in third gear when tested officially on the tractor testing course with steel wheels and lugs.

TABLE 4 AVERAGE CONTACT AREA PER WHEEL IN SQUARE INCHES OF FIVE DIFFERENT TIRE SIZES, THE STATIC WEIGHT OF THE TRACTOR REMAINING AS IT WAS FOR THE CONSTANT WEIGHT TESTS

Pressure, lb	9.00x24	11.25x24	12.75x24	13.50x24	9.00x36
8	87.95	93.05	110.76	112.28	94.96
16	59.74	58.65	72.88	73.99	64.46
Difference	28.21	34.40	37.88	38.29	30.50
Per cent gain	32.07	36.96	34.20	34.10	32.10

In attempting to determine the effect of changing tire size on traction by logic without experimental data, it seems right to most people to assume that by increasing the size of the tire, they can increase a tractor's traction, and to assume further that this assumed increase in traction is due to an increase in contact area. Table 4 has been inserted more for the purpose of giving some figures to ponder over than to give a basis for conclusions. One thing would seem to be apparent, namely, that the per cent increase in contact area is greater than the per cent increase in traction where an increase in traction did occur. It throws no light on the condition on the tractor testing course where traction was lost in decreasing the inflation pressure from 16 pounds to 8 pounds.

This table was prepared from measurements taken from the tires used in these tests. The contact area of a tire with tread is subject to some variation due to the personal factor involved in outlining the same. It should therefore be kept in mind that Table 4 is not submitted as the result of an exhaustive investigation of the subject.

Light and Its Effects on Plant Growth

By Robert B. Withrow

PROBABLY the earliest extensive investigation of the practical possibilities of artificial sources of radiation for the forcing of plant growth was that of Bailey (3)* who in 1891 reported experiments with street arc lamps obtained from a local utility company at Ithaca, N. Y. While some of Bailey's results were favorable and indicated the possibilities of artificial light sources in stimulating growth, they were quite variable and injurious effects were noted in many cases due to the high intensity of ultra-violet radiation present. Since these early experiments, the studies on the forcing of plant growth with artificial sources of radiation have resolved themselves into three general types. These include (a) studies with ultra-violet radiation, especially with regard to those regions which are normally present in sunlight and are removed by ordinary window glass; (b) the use of high intensities of visible light for supplementing daylight during cloudy weather or as a whole or partial substitute for sunlight; and (c) the application of low intensities of visible radiation for prolonging the normal daylight period.

ULTRA-VIOLET RADIATION

Popp and Brown (11) have recently compiled the results of a large number of investigations on the so-called stimulative effects of ultra-violet radiation and have come to the conclusion that, while ultra-violet may at some future time be shown to have a stimulative influence on plant growth, such has not been conclusively proven by any of the investigations to date. It may generally be considered that ultra-violet sources of radiation such as sun lamps and arcs which produce radiation of wavelengths shorter than 3000 Angstrom units have not proven themselves of value in the commercial forcing of plant growth.

HIGH INTENSITY VISIBLE RADIATION

Visible radiation is of vital importance to the normal functioning of many of the processes which take place in the growing plant. From the practical aspects of the problem, these processes may be arbitrarily divided into two general classes, (a) those processes which require relatively high intensities, above 100 foot-candles, and (b) those which require low intensities, below 20 foot-candles.

Photosynthesis, which is the process by which plants convert radiant energy into chemical energy, is the only process which is definitely known at the present time to fall into the first class. It is this process which appears to be the primary limiting factor preventing the normal growth of plants during cloudy weather, aside from day length limitations. In all other respects, greenhouse plants appear to grow quite normally in light intensities of 100 foot-candles or even less.

The other light requirements, in so far as they have been individually studied in herbaceous plants, appear to be adequately supplied with intensities below 20 foot-candles. The synthesis of chlorophyll, the influence on the permeability of the cells, phototropic responses, the disappearance of etiolated characteristics of plants grown in the dark, and photoperiodic effects may all be induced by visible light intensities below 20 foot-candles, apparently to a sufficient degree for normal growth processes.

Sunlight intensities in the midwestern agricultural regions of the United States reach values of 10,000 to 12,000 foot-candles (8) at noon during June and July. However, 2000 to 3000 foot-candles are probably all that most floricultural crops can use effectively as indicated by results obtained in cloth houses (2) and studies of photosynthetic rates (7).

To sustain vigorous growth of plants in windowless greenhouses entirely without the aid of sunlight would probably require intensities of 1000 foot-candles for a period of 12 hours per day. Using 1000-watt incandescent lamps having an initial output of 18 lumens per watt and assuming an operating efficiency of 80 per cent, the power consumption would be 0.83 kilowatt-hour per square foot per day. On a yearly basis of 360 days, the cost at 2 cents per kilowatt-hour would be $6.00 per square foot. Statistics on the cost of operation of greenhouses recently compiled for the state of Michigan (4) show the total average cost per square foot under glass per year to be in the vicinity of 75 cents to $1.00 per square foot of bench space. This cost takes into account all items such as depreciation on equipment, interest costs,

FIG. 1 A COMMERCIAL LAMP INSTALLATION IN THE GREENHOUSES OF GEORGE BALL AT WEST CHICAGO, ILLINOIS. A SINGLE ROW OF 100-WATT LAMPS IN RLM REFLECTORS ARE USED TO LIGHT TWO BENCHES

Presented before the Rural Electric Division of the American Society of Agricultural Engineers at Chicago, December 4, 1935.

Author: Research assistant in light and plant growth, department of horticulture, Purdue University Agricultural Experiment Station.

*Figures in parenthesis refer to literature cited at the end of this paper.

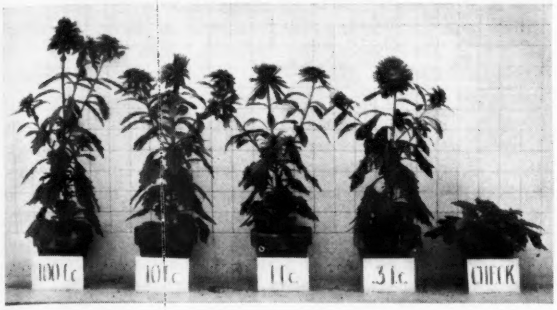


FIG. 2 RESPONSE OF CHINA ASTER TO VARIOUS MAZDA LAMP INTENSITIES FROM 0.3 TO 100 FOOT-CANDLES APPLIED AT NIGHT TO PROLONG SHORT WINTER DAYS TO A TOTAL OF EIGHTEEN HOURS

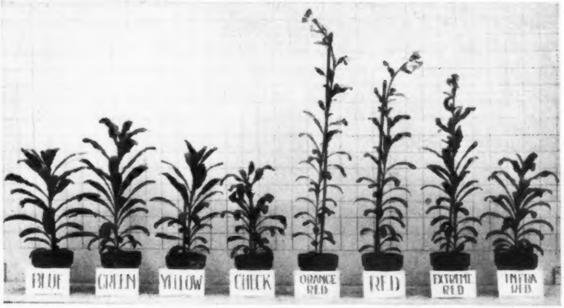


FIG. 3 RESPONSE OF STOCK TO LOW INTENSITIES OF EQUAL ENERGIES OF SELECTED REGIONS OF THE VISIBLE SPECTRUM. THE LIGHT WAS APPLIED AT NIGHT TO PRODUCE A TOTAL DAY LENGTH OF 18 HOURS

labor, fuel, supplies and others. Thus the cost of electrical power alone for a windowless house would be six times all other costs existing in a conventional glass house.

Using artificial radiation to supplement sunlight during dark weather only, is a much more economical procedure and appears to have commercial possibilities. Dark weather frequently involves intensities of as low as 100 to 300 foot-candles during the late morning and early afternoon. During this kind of cloudy weather plants grow very slowly. It would probably be necessary to at least double these lowest values with artificial radiation to satisfactorily accelerate growth. Assuming that 200 foot-candles of artificial radiation are supplied for a period of four hours each day for only the three darkest months of the year, the power cost would be 10 cents per square foot per year. Figured on the basis of the months when in use, the power cost becomes 40 per cent of the total operating cost. This is not considering the lamp replacement and equipment costs which would increase the above figure by at least 25 per cent. The heat generated by the lamps would somewhat decrease the fuel consumption, but this item is only 12 cents per square foot per year in existing glass houses.

It is reasonable to expect that such an application of power to supplement winter daylight during the most unfavorable periods would be justified over high-priced crops such as the gardenia, camelia, and orchid, and over crops which are of full value only on specific dates such as the Easter lily. It may also become a profitable procedure to use high wattage lamps to double or treble dark weather daylight over seedlings which are still in the seed flat. In this manner from 50 to 200 seedlings may be irradiated per square foot of bench space and the cost per seedling would be relatively low. The new high-intensity mercury arcs, which have twice the luminous efficiency of the incandescent lamp, offer added possibilities in this field and may eventually shift the balance more in favor of the use of high artificial light intensities in the greenhouse.

Recently Arthur and Porter (1) have described a similar application of artificial radiation in a new type of insulated greenhouse in which the lamps serve to supplement the daylight coming in through a window in the roof and to supply all the heat necessary. The item of fuel cost for the conventional greenhouse, while an important one, actually represents only 12 per cent of the total cost of operation and does not justify excessive expenditures in the way of electrical power or higher first cost in the house itself. They estimate that the power cost for their house having inside dimensions of 19 by 8 feet would be 36 cents per day, with power at 2 cents per kilowatt-hour. On a yearly basis, this would be 85 cents per square foot. Of course, the lamps would not have to be operated for heating for more than six months during the year but for the most active growth, the window alone would not seem adequate for the entrance of sufficient solar radiation.

Such an arrangement presents many other problems, especially due to the high temperatures present. Too often temperature is not given sufficient consideration in experimental work of this type. It does not seem to be generally understood by many that fuel economy is the least important reason for the commercial practice of using relatively low temperatures for certain crops. Stock, for instance, has been recently shown to be incapable of flowering at temperatures much above 65 degrees (Fahrenheit). Other crops such as the carnation, sweet pea, snapdragon, and chrysanthemum produce flowers of poor keeping quality, and oftentimes weak stems, when grown at the higher temperatures most favorable to the rose and gardenia, for instance. The cool house crops produce the highest quality flowers at temperatures of from 45 to 55 degrees and higher temperatures are detrimental. Many of these cool house plants will actually grow faster and possibly flower more abundantly at the higher temperatures but the material is of little commercial value. Disease and insect pests are also less troublesome at lower temperatures. The thermostats in the insulated greenhouse experiment just mentioned were adjusted to switch on the lights so as to maintain a temperature of 72 to 78 degrees at first and later reduced to 62 to 68. Four of the ten plants used were of the cool house type.

It therefore appears safe to conclude that, at the present time, high intensities of artificial radiation can not profitably compete directly with sunlight in commercial production of greenhouse crops. Artificial sources may, however, have commercial possibilities in aiding the grower to solve some of his dark weather problems as have occurred during the past winter.

SPECIAL APPLICATIONS FOR HIGH-INTENSITY LIGHTING

There are several special applications in plant production which have not received adequate attention as a potential use for high-intensity electric lighting. These include private greenhouses and solariums, the production of show plants during cloudy weather, and the maintenance of vigorous growth in display windows of retail florists in locations where direct sunlight is seldom if ever available. So far as the author is aware, there are not sufficient experimental results available to make possible specific recommendations although there is unquestionably a very real demand for this type of application.

In 1920 Garner and Allard (5) reported their classical studies of the effect of day length on the flowering responses of plants. This work marked the real beginning of the commercial application of electric lights to the forcing of greenhouse crops. In this original report they showed that intensities of 5 foot-candles were sufficient to influence the growth habit of many plants if applied during the night. In view of the fact that intensities of sunlight reach values as high as 10,000 foot-candles or more and seldom become much less than 200 foot-candles, even in the darkest winter weather, it is obvious that this low intensity of 5 foot-candles is not important in the total energy relationships of the growing plant but rather the effect is due to a controlling mechanism dependent largely upon the duration of the total lighted period. Garner and Allard found that there were three general classes of plants, based upon their flowering responses to day length. From the standpoint of the commercial application of artificial lights, these three classes may be stated as follows: (a) long day plants which may be brought into the flowering condition early or made to flower more profusely by artificially lengthening the day; (b) short day plants the flowering of which may be delayed by increasing the day length; and (c) those which are relatively indifferent to day length in their flowering response.

Later investigations have shown that the low limit of intensity for controlling the flowering responses of commercial crops under greenhouse conditions varies greatly with different plants. With stock, this threshold value is in the vicinity of 5 to 10 foot-candles. For China aster, one-third of a foot-candle appears to be practically as effective as 100 foot-candles in inducing earlier blooming (Fig. 2). Even one-tenth of a foot-candle or about twice the intensity of bright moonlight is sufficient to markedly influence the flowering of the Heart of France aster. Commercially, growers are now successfully using intensities ranging from one to 25 foot-candles for controlling the flowering of various crops.

Electric lights have largely been used for the forcing of the long day class of plants in which it has been desirable to bring the crops in earlier and thus decrease the time and expense required for production of flowers as with stock and aster. Thus far, the only commercial application to the short day plant is with chrysanthemum. Some growers are using lights to delay flowering in order to have blooms in January and February when there is a scarcity of greenhouse cut flowers.

Most of the lighting installations placed in greenhouses have involved rows of low-wattage lamps ranging from 15 to 100 watts to light one or two benches at a time (Fig. 1). While such a practice is satisfactory for a grower who has a house of miscellaneous crops, only a few benches of which are to be lighted, it is quite uneconomical over large areas. The 1000-watt general service lamp is approximately twice as efficient in visible energy output (lumens per watt) as a 50-watt lamp. The larger lamps also involve fewer units, thus materially reducing the first cost. For these reasons, it is more economical to light a whole greenhouse with a few high-wattage lamps than with many low-wattage lamps. The question of aisles which are uniformly lighted in the case of the larger lamps hardly influence the problem because even with the most efficient low-wattage reflectors, much light is scattered into aisles and other areas where it is not utilized by plants.

The most recent studies (13) on the effect of the different wavelengths of the visible spectrum when the radiation is applied during the winter to increase the day length have shown that it is the red end of the visible spectrum which is largely effective in bringing long day plants into flower and in delaying the blooming of short day plants (Fig. 3). Lengthening the day with green or yellow light has practically no effect. Blue radiation produces results somewhat similar to red light but they are much less pronounced. When the effects of the red radiation of an incandescent lamp are compared with those of the full radiation of an incandescent lamp, it is found that almost identical results are obtained. Thus, the incandescent lamp with its relatively high energy in the red is well suited as a source for the forcing of plants. In this country, the more efficient gaseous sources such as the neon lamp have not found favor with the commercial growers largely because of the high first cost. In Germany and the Netherlands, neon lamps are beginning to find general application for this type of work.

Studies (14) regarding the time of night at which the lights are best applied and the duration of the lighted period indicate that the lights may be used at any time during the night that is suitable to the grower and similar results may be obtained regardless of the time. The duration of the period of artificial light should not usually be less than four hours and for economic reasons, not more than six. This subject immediately brings up the problem of off-peak loads and the possibility for the grower to apply his lights during such periods, using time clock control, thus taking advantage of lower power rates.

It should be generally recognized that lengthening the day artificially with low-intensity radiation (below 100 foot-candles) is not a substitute for dark weather. Commercial growers sometimes fail to recognize the significance of this fact and believe that low intensity radiation should be used only during darker weather. This is not true. The benefits to be derived from the use of low intensity artificial light at night are solely a proposition of influencing time of flowering through control of day length and not one of building chemical energy in the form of carbohydrates for growth.

Some of the effects of lengthening the day other than those on the flowering habit may include soft growth, weak stems, longer stems, a relatively large top in proportion to root, and less branching. It is advisable for the grower to wait until the seedling plant has developed a strong root system before applying lights. It is also well to turn the lights off several weeks before the flowers are to be cut. Otherwise, weak flowering stems may result.

Once lights are applied over a crop as China aster which normally fails to flower satisfactorily during the winter season, they should not be discontinued until the flowering stems are sufficiently long for cutting purposes. If the lights are discontinued too early, the plants may immediately come into flower on stems too short for sales purposes. Several cases of unsatisfactory flowering of aster as a result of too short a period of lighting have been brought to my attention.

The usual cultural practices with regard to the use of inorganic fertilizers, watering and disbudding may need to be somewhat modified by the grower when he used electric lights in his greenhouse for plant forcing. There are several bulletins available which discuss the forcing of greenhouse crops with low-intensity electric light and the treatment required by various plants (9, 10, 12).

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2 Arthur, J. M. and W. D. Stewart. Plant growth under shading cloth. (Abstract). Am. Jour. Bot. 18: 897. 1931.

3 Bailey, L. H. Some preliminary studies of the influence of the electric arc lamp upon greenhouse plants. Cornell Agr. Exp. Sta. Bull. 30. 1891. *(Continued on page 184)*

The Engineering Reorganization of Farms

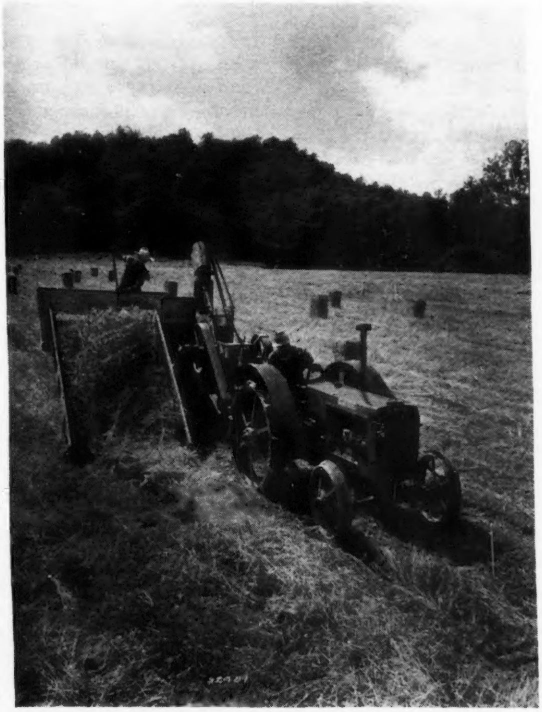
By N. A. Kessler

IT SEEMS apparent that under our agricultural system, as it is now developing, efficiency in farming is becoming more important and that agricultural engineering in all its phases must continue to play an important part in any farming program. It is self-evident that not all engineering equipment, structures, or methods can be recommended for all farms, since we not only have variety in types of farming but also variation within each type. The object of a project, which has been called the "Engineering Reorganization of Farms," is to determine the needs of individual farms for engineering improvements and the benefits which will be derived from their application. While each farm is a problem in itself, it is believed that a study of a number of farms in each agricultural region will yield facts from which generalized conclusions may be drawn.

Surveys of over a hundred farms in seven different states show that many have fields which are nonproductive or partially so because of lack of drainage, soil erosion, or the presence of stumps and boulders. In most cases there has been little or no change from the original field arrangement of the farm. The fields are small and frequently irregular in shape, preventing efficient use of tractor-drawn machinery. Buildings are frequently unadapted to the purpose for which they are used and the location of new buildings is often determined by the availability of space rather than convenience. Power is usually excessive and the machinery frequently obsolete or inefficient.

Preliminary to the inauguration of any project all pertinent facts should be determined as nearly as possible. The physical survey, which is preliminary to a farm development program, develops only a part of the facts which must be considered, since physical improvements should be based on a detailed knowledge of the crop rotation, livestock, and other purely agricultural features of the farm program. The farm business must be considered as a unified structure, and each element given its correct proportion in regard to every other element and to the farm business as a whole. Since the planning of purely agricultural features is outside the field of agricultural engineering, the cooperation of specialists in these lines has been sought in working out the detailed plans for each farm.

A measure of results will be indicated by the increase in farm income or production as indicated by the farm records, and an increase in efficiency of operation by the saving in time in performing the different farm operations.



The method followed in this work is to draw to scale a map of each farm, showing all details. A crop rotation is determined by the farm management authorities and a new field layout is made which includes all areas capable of being developed. These changes are discussed with the farmer and have his approval. The new field layout is plotted on the map giving the farmer a better conception of the problem and enabling him to work more intelligently. The map is also of value in that it serves as a permanent record of improvements which are made from time to time. A banker who was shown one of these maps by a cooperator, became interested in the project and expressed a desire to have a map made of his farm because he realized its value. He no doubt also appreciated the value to the farmer of a planned farm program in developing the farm to its highest efficiency.

Of the farms now being studied, few were found which had a suitable field arrangement for the area under cultivation. The new field arrangement determined upon materially decreased the number of fields and increased the size so they could be worked efficiently. In some cases there was less fencing material required for the new arrangement than that already on the farm, and there were only a few cases where the purchase of new material was necessary. In a number of cases, the farm management authorities found that there was a lack of balance of animal units and possible pasture crops, or a lack of balance in the rotation itself. Under the new plan all phases are balanced with one another.

The power and machinery necessary for operation under the new plan is determined by the type of farming, the area, and the crop rotation. As the developments occur, power or machinery replacements may be made. The amount of change necessary may vary greatly on each farm, depending on the machinery already there, the change in crop rotation, and the speed with which uncultivable areas are improved. Usually the machinery on the farm is sufficient for a time with little need for immediate replacement. It is, however, possible that the immediate purchase or replacement of machinery may be advisable in some cases. There may be instances where the joint ownership of some types of machinery is feasible and advisable. This will not only reduce the cash outlay but will reduce the overhead expense and make possible full cooperation among the owners to the advantage of all concerned.

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The type of power to be used is governed by the location, type of farming, and inclination of the individual farmer. A study of the power used on farms now cooperating in the Minnesota project has shown that in practically all cases there was an excess of power because few, if any, horses were disposed of when a tractor was bought. This no doubt is also true in other states.

Frequently some portion of the farm cannot be cultivated because of the lack of drainage. Those areas which have an outlet are included in the field set-up under the new plan. Where there is a single, large wet or low area, improvement of which is too costly to be done at one time, plans may be made to lay tile periodically and in such quantities as can be financed by the farmer. Small low or wet areas which prevent the complete cultivation of a field may be drained first, since the cost is relatively small and the increase in efficiency large. In cases where there is no outlet and no prospect of one being made available except at excessive cost, the land may be put to some other use. In Minnesota, reed canary grass is frequently recommended for low areas since it will grow under such conditions. Our studies in Minnesota have indicated that many of the drainage ditches which should serve as outlets for tile drains have become filled with sediment or vegetation. Where this condition exists, the tiling problem becomes rather difficult to solve until the ditch is improved.

The areas requiring erosion control are indicated on the map and each should be given its proper place in the development program. Since farmers are becoming more erosion conscious and terracing machinery is becoming more readily available at lower cost, terracing will be done at a more rapid rate than has been the case in the past. Those areas which are too severely eroded to be included with the cultivable land can well be planted to forest trees to prevent further damage and as a source of building material or fuel. In any case, a woodlot stocked with selected species should be included in the new set-up.

While new building occurs infrequently in the life of the average farmer there may be instances where buildings are a major problem. The building sites with the location of each building on the site should be shown on the map. In many cases a change in the floor plan of a building will make it more suitable for the purpose which it is used or may permit the installation of labor and time-saving machinery. In some cases plans may be made for the convenient location of new buildings the construction of which is under consideration. Where the reorganization plan is based on a change in the type of farm business, the buildings may require considerable alteration. This happens to be true of a number of farms studied in the Ohio project.

While stumps and boulders are not a major farm problem in the well settled areas, they are occasionally to be found. When present in a field these obstacles prevent the efficient use of machinery and too frequently are the cause of costly damage or breakage. Early removal of these should be considered in the reorganization plan. Where the removal of trees is necessary, this should be done as soon as possible to permit at least partial decay of the stumps before removing them.

In many cases the new field arrangement does not require the purchase of new fencing material and in some cases there may be a surplus. Since fence changes do not usually require the immediate purchase of new material, they can be made readily.

Considering the problems just enumerated, it can be seen that the development of a reorganization plan in an orderly and progressive manner is a problem which requires considerable forethought and planning. Each phase must be given its proper place depending on cost and need. Estimated costs of each type of improvement are of considerable help in working out the program for each farm.

In addition to the farm reorganization project for the developed sections, is one for the cutover sections. This project is one of organization rather than reorganization. The procedure in this case also includes a map showing all details including size and amount of brush and stumps. Areas of such size as can be cleared each year will be laid out so that the total amount of cleared land together with the crop rotation, power, machinery, etc., any given year will be known. This will permit planning for the purchase of explosives, crop rotations, the purchase of new machinery, and the construction of buildings. The plan will include the location of the building site together with the proposed location of all buildings, so that as each is constructed it will occupy its permanent position. The thought is that where a building is to be used temporarily for some other than its main purpose, it should be of such design that changes can be made at little cost. The project offers a splendid opportunity to study the progress made by the settler under a definite plan to determine how the time involved in working the gradually increasing cultivated acreage will affect the rate of clearing. If clearing cost records are kept, it will make a splendid opportunity to obtain this data under the settler's working conditions. Since farm cost account records will be kept, economic studies will also be made.

Economic conditions during the past four years have not been favorable for farm improvements on a very large scale; however, some tiling has been done and a serious effort has been made by our cooperators to at least make such changes which require the expenditure only of labor. Each year a progress map has been made for each cooperator. This map shows the acreage and location of each crop grown and the improvements made. It also serves as a permanent record to which the cooperator may refer in later years.

In both of these projects the development of a good plan is essential but equally important is that the plan be followed as nearly as conditions will permit. The rate of change from the old to the new will be governed by the conditions prevailing on each farm and will vary accordingly. The full cooperation and confidence of the farmer can be gained if the purpose of the project is carefully explained and the value of a long-time development plan is fully understood. It is needless to say that the farmer must also have some part in the program planning.

Stabilization by Engineering

As FOOD production concentrates more and more into the hands of an ever smaller minority of the population, the greater the hazard of hardship to the non-agricultural population if natural causes disturb the continuity of crop yield. Thanks to the productiveness of modern agriculture, the threat of famine seems remote. But we have recent and ample evidence that excess, or seeming excess, of production can create widespread hardship as could shortage. Stabilization by engineering can escape the curse of both extremes, and at the same time avoid the difficulties of arbitrary control.

Being inherently efficient, in that it makes for continuous operation of our farm plant at normal capacity, stability by engineering brings us closer to those seeming incompatibles—high income for the farmer, and low costs for consumers.

Loaded Spoked Vehicle Wheels

By Jos. B. Reynolds and F. L. Ehasz

THOUGH the invention of the vehicle wheel antedates the memory of man, no complete analysis of the forces coming into play in the loaded vehicle wheel has yet appeared. The mathematical analysis for elastic disk wheels under certain loadings has been accomplished by Hertz and by Michell. Coker has studied the general nature of stresses produced in the construction of railway car wheels, and Pippard, White, and Baker those arising in wire wheels under particular types of loading. Certain photoelastic studies of loaded wheels have, also, been presented by Coker and Filon.

The circumstance for which we propose to develop the mathematical theory, and support it by photoelastic tests, is that of a spoked wheel at rest on the level with a vertical load applied at the center of the wheel. It is assumed that all forces lie in one vertical plane containing the neutral axis of the rim of the wheel and that the proportional limit is at no time exceeded. It is also assumed that the spokes remain at right angles to the rim and make an invariable angle with each other at the center of the wheel.

The solution is based upon the formulas for elastic rods, curved and straight beams, and is developed for a wheel of even-numbered spokes for two critical positions: first, when the two lowest spokes make equal angles with the vertical; second, when two spokes are vertical. The first case is that of minimum stresses in the two lowest spokes and of maximum moment in the rim. The second case is that of maximum stress in the spokes and minimum moment in the rim. In each case only half the wheel need be considered because of symmetry with the vertical.

The plan of this paper is to present the fundamental formulas upon which the analysis is based and give an exposition of the manner in which they are used. Additional formulas for rim, spoke, and center deflections applicable for the two critical positions will then be derived. Detailed applications of the general theory to a 4- and 6-spoked wheel for the first position have been worked out and the former will be presented. The method for any number of spokes is outlined. Simplified solutions for both critical positions will be given for four and six spokes and indicated for any number.

Finally experimental checks on the theory made by the photoelastic method will be presented and the paper closed with a short bibliography on the subject.

NOTATION

A = section area of rim

A' = section area of spoke

$B = Aek^2l/A'E'r^3$; $B' = k'^2/l^2$

d = vertical deflection of center of wheel

E, E' = Young's modulus for the rim and for the spokes, respectively

f = lateral deflection of end of spoke

k, k' = principal radius of gyration with respect to axis perpendicular to the plane of the wheel for a cross section of the rim and of a spoke, respectively

l = length of spoke

M = general bending moment in rim (counterclockwise being positive)

$M_1, M_2, \ldots, M_s, \ldots M_n$ = end bending moments in spokes $1, 2, \ldots, s, \ldots n$

M_o, M_x = bending moments in rim at bottom and top of wheel, respectively

$m_1, m_2, \ldots, m_s, \ldots m_n$ = bending moments in the rim resulting from a unit normal force at points $1, 2, \ldots, s, \ldots n$ on the neutral axis of the rim

m_x, m_y, m_u = bending moments in the rim resulting from unit forces at designated points in directions indicated by x, y, u, respectively.

N = resultant force tangential to the rim of the wheel at a general point due to all forces acting; positive in the sense of increase of θ.

$2n$ = number of spokes in the wheel

$n_1, n_2, \ldots, n_s, \ldots n_n$ = resultant forces tangential to the rim at a general point due to unit normal forces at points $1, 2, \ldots, s, \ldots n$; positive in the sense of increase of θ

n_x, n_y, n_u = tangential stresses due to unit forces at designated points in the directions indicated by the subscripts x, y, u, respectively

$P_1, P_2, \ldots, P_s, \ldots P_n$ = compressive forces in spokes normal to the rim at points $1, 2, \ldots, s, \ldots n$

P_o, P_x = rim tension forces at bottom and top of the wheel, respectively

r = radius of neutral axis of wheel

$S_1, S_2, \ldots, S_s, \ldots S_n$ = shears at ends of spokes $1, 2, \ldots, s, \ldots n$

U_x, U'_x = special integrals

W = load on wheel applied vertically at center

$\alpha_1\ \alpha_2, \ldots, \alpha_s, \ldots \alpha_n$ = angular position of spokes $1, 2, \ldots, s, \ldots n$ with vertical, measured counterclockwise from bottom

$\delta_1, \delta_2, \ldots, \delta_s, \ldots \delta_n$ = normal deflections of points $1, 2, \ldots, s, \ldots n$ on rim

δ_x = horizontal deflection of topmost point on rim axis

$\Delta_1, \Delta_2, \ldots, \Delta_s, \ldots \Delta_n$ = total strains in spokes $1, 2, \ldots, s, \ldots n$

$\delta\phi$ = angular deflection of spoke

$\delta\phi_1, \delta\phi_2, \ldots, \delta\phi_s, \ldots \delta\phi_n$ = angular deflection of rim at points $1, 2, \ldots, s, \ldots n$

$\delta\phi_x$ = angular deflection of topmost point on rim.

FUNDAMENTAL FORMULAS

The formulas for curved beams when adapted to a beam of constant radius of curvature give

$$\delta_u = \frac{r}{AE}\int N\left(n_u + \frac{m_u}{r}\right) d\theta + \frac{r}{EI}\int M m_u\, d\theta \qquad [1]$$

for linear deflection, and

$$\delta\phi = \frac{1}{AE}\int N d\theta + \frac{r}{EI}\int M d\theta \qquad [2]$$

for angular deflection.

Authors: Respectively, professor of mathematics and theoretical mechanics and research fellow in civil engineering, Lehigh University.

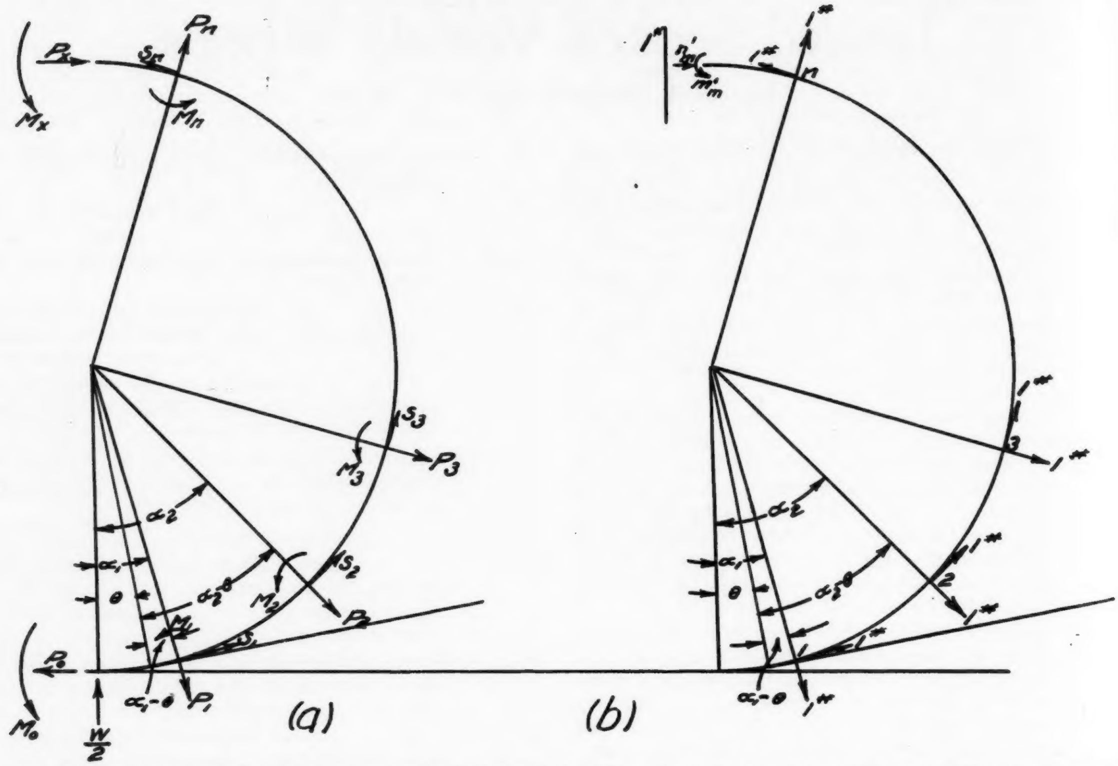

FIG. 1 (A) RIGHT HALF OF THE WHEEL IN THE FIRST POSITION WITH THE ACTUAL LOADING ON THE RIM AS TRANSMITTED FROM THE SPOKES SHOWN. (B) DIAGRAM FROM WHICH TO READ THE VALUES OF THE TANGENTIAL FORCE AND COUNTERCLOCKWISE MOVEMENT, RESPECTIVELY, DUE TO A UNIT LOAD AT ANY CHOSEN POINT

The formulas for a cantilever beam expressing angular deflection, $\delta\phi$, in terms of the free-end linear deflection, f, and free-end shear, S, and moment, M, are

$$EI\ \delta\phi = M\,l + \tfrac{1}{2} S\,l^2 \qquad [3]$$

and

$$EIf = \frac{1}{2} M\,l^2 + \frac{1}{3} S\,l^3. \qquad [4]$$

For a beam under compressive force, P, along its length, the deformation is

$$\Delta = \frac{P\,l}{AE} \qquad [5]$$

In the general theory it is assumed that the spokes act under compressive forces $P_1 \ldots P_n$ and shears $S_1 \ldots S_n$. These, in turn, react upon the rim and produce linear and angular deflections given by [1] and [2]. The angular deflection of the spoke at its outer end, being the same as that of the rim at the point of juncture, leads to a relation between the angular deflection of the rim and the shear and moment in the spoke provided by [3]. The relative linear deflection of the inner and outer ends of the spoke is related to the tangential deflection of the rim at the outer end of the spoke by [4]. Finally the deflection of the inner end of the spoke in the direction of its length is greater than that of the outer end by the compression, Δ, given by [5]. The derived formulas are the mathematical formulation of these relationships. In the simplified theory the shears and moments in the spokes are neglected.

DERIVED FORMULAS

Fig. 1(a) shows the right half of the wheel in the first position with the actual loading on the rim as transmitted from the spokes shown. The reaction, $\tfrac{1}{2}W$, of the ground is shown as well as the reactions M_o, M_x, and P_x of the left half of the rim. From this figure we see that the force, N, acting tangentially to the rim in the sense of increase of θ in the range from spoke s to spoke $s + 1$ is given by

$$N = \sum_{m=s}^{m=n} P_m \sin(\alpha_m - \theta) + \sum_{m=s}^{m=n} S_m \cos(\alpha_m - \theta) + P_x \cos\theta \qquad [6]$$

in which $\alpha_m = (2m - 1)\ \pi/2n$. In the same range the counterclockwise moment acting upon the rim, M, is given by

$$M = \sum_{m=s}^{m=n} \left\{ M_m + S_m r\,[1 - \cos(\alpha_m - \theta)] - P_m r \sin(\alpha_m - \theta) \right\} - P_x r\,(1 + \cos\theta) + M_x. \qquad [7]$$

Fig. 1(b) is a diagram from which to read the values of the tangential force and the counterclockwise moment, respectively, due to a unit load at any chosen point. The thrust n'_m and the moment m'_m are those that must be introduced at the top of the wheel to satisfy the requirement that

there shall be neither horizontal nor angular deflection at that point for a unit normal load acting upon the rim at point m. The thrust n''_m and moment m''_m are the corresponding values for the case when the unit load at point m is applied tangentially.

When a unit load is applied at any point on the rim, the resulting tangential tension at any place on the rim determined by the angle θ is designated by the letter n_m, and the resulting counterclockwise moment by the letter m_m. The primed letters designate force and moment at the highest point only and are deflection requirements for unit loads at the outer spoke ends. The unprimed letters refer to general tension and moment, variable over the length of the rim as θ varies.

The values found for normal unit loads are

$$\left.\begin{aligned} n'_m &= -\frac{\alpha_m}{\pi}\sin\alpha_m \\ m'_m &= \frac{r}{\pi}\left(1-\frac{k^2}{r^2}\right)(1-\cos\alpha_m) \\ &\quad -\frac{r\alpha_m}{\pi}\sin\alpha_m \end{aligned}\right\} \qquad [8]$$

and those for tangential unit loads

$$\left.\begin{aligned} n''_m &= -\frac{1}{\pi}\sin\alpha_m-\frac{\alpha_m}{\pi}\cos\alpha_m \\ m''_m &= \frac{r}{\pi}\left(2-\frac{k^2}{r^2}\right)\sin\alpha_m \\ &\quad -\frac{r}{\pi}\alpha_m(1-\cos\alpha_m). \end{aligned}\right\} \qquad [9]$$

When using [1] to determine deflection normal to the rim, δ_m, at the point, m, the values of the tangential tension and rim moment are seen to be

$$\left.\begin{aligned} n_m &= \sin(\alpha_m-\theta)+n'_m\cos\theta, \text{ and} \\ m_m &= -r\sin(\alpha_m-\theta) - \\ &\quad n'_m r(1+\cos\theta)+m'_m \end{aligned}\right\} \qquad [10]$$

When using [1] to determine the deflection tangential to the rim, δ'_m, at the point, m, the values of the tangential tension and rim moment are

$$\left.\begin{aligned} n_m &= \cos(\alpha_m-\theta)+n''_m\cos\theta \text{ and} \\ m_m &= r[1-\cos(\alpha_m-\theta)] \\ &\quad -n''_m r(1+\cos\theta)+m''_m \end{aligned}\right\} \qquad [11]$$

When using [1] to set up an expression for the horizontal deflection, δ_x, of the highest point

$$n=\cos\theta \text{ and } m=-r(1+\cos\theta). \qquad [12]$$

In order to simplify the notation we introduce two summations defined by

$$U_x=\sum_{m=1}^{m=n}\left\{\left(\frac{k^2}{r^2}-1\right)P_m\int_0^{\alpha_m}\sin(\alpha_m-\theta)\,d\theta\right.$$

$$+\left(\frac{k^2}{r^2}-1\right)S_m\int_0^{\alpha_m}\cos(\alpha_m-\theta)\,d\theta$$

$$\left.+\left(S_m+\frac{M_m}{r}\right)\alpha_m\right\}-\pi\left(P_x-\frac{M_x}{r}\right) \qquad [13]$$

and

$$U'_x=\sum_{m=1}^{m=n}\left\{P_m\int_0^{\alpha_m}\sin(\alpha_m-\theta)\cos\theta\,d\theta\right.$$

$$+S_m\int_0^{\alpha_m}\cos(\alpha_m-\theta)\cos\theta\,d\theta$$

$$\left.-\left(S_m+\frac{M_m}{r}\right)\sin\alpha_m\right\}+\frac{\pi}{2}P_x. \qquad [14]$$

We now set up expressions for the horizontal and angular deflection, δ_x and $\delta\phi_x$, of the highest point of the rim by means of equations [1] and [2] and tensions and moments from [6], [7], and [12]. When the integrals for the successive ranges are collected, the results take the forms

$$\frac{EI\,\delta_x}{r^3}=U_x+U'_x \qquad [15]$$

and

$$\frac{EI\,\delta\phi_x}{r^2}=U_x. \qquad [16]$$

Since both these deflections must be zero, we have the results

$$U_x=0 \text{ and } U'_x=0. \qquad [17]$$

When we set up the expression for the normal deflection δ_s, by use of equations [1], [6], [7], and [10] for the different ranges and collect the integrals, we find terms of the forms $U_x\left(n'_s-\frac{m'_s}{r}\right)$ and $U'_x n'_m$, which disappear, leaving

$$\frac{EI\,\delta_s}{r^3}=\sum_{m=1}^{m=s}\left\{P_m\int_0^{\alpha_m}\sin(\alpha_m-\theta)\right.$$

$$\sin(\alpha_s-\theta)\,d\theta+S_m\int_0^{\alpha_m}\cos(\alpha_m-\theta)$$

$$\sin(\alpha_s-\theta)\,d\theta-\left(S_m+\frac{M_m}{r}\right)$$

$$\left.\int_0^{\alpha_m}\sin(\alpha_s-\theta)\,d\theta\right\}+\frac{P_x}{2}\alpha_s\sin\alpha_s$$

$$+\left(P_x-\frac{M_x}{r}\right)(1-\cos\alpha_s)$$

$$+\sum_{m=s+1}^{m=n}\left\{P_m\int_0^{\alpha_s}\sin(\alpha_m-\theta)\right.$$

$$\sin(\alpha_s-\theta)\,d\theta+S_m\int_0^{\alpha_s}\cos(\alpha_m-\theta)$$

$$\sin(\alpha_s - \theta)\, d\theta - \left(S_m + \frac{M_m}{r}\right)$$

$$\left.\int_0^{\alpha_s} \sin(\alpha_s - \theta)\, d\theta \right\} \qquad [18]$$

When the expression for angular deflection, $\delta\phi_s$, is set up by [2], [6], and [7] and the integrals collected for the different ranges we find

$$\frac{EI\,\delta\phi_s}{r^2} = \left(\frac{k^2}{r^2} - 1\right) \left\{ \sum_{m=1}^{m=s} P_m \right.$$

$$\int_0^{\alpha_m} \sin(\alpha_m - \theta)\, d\theta + S_m$$

$$\left.\int_0^{\alpha_m} \cos(\alpha_m - \theta)\, d\theta + P_x \sin\alpha_s \right\}$$

$$+ \left(\frac{k^2}{r^2} - 1\right) \left\{ \sum_{m=s+1}^{m=n} P_m \right.$$

$$\left.\int_0^{\alpha_s} \sin(\alpha_m - \theta)\, d\theta + S_m \int_0^{\alpha_s} \cos(\alpha_m - \theta)\, d\theta \right\}$$

$$+ \sum_{m=1}^{m=s} \left(S_m + \frac{M_m}{r}\right) \alpha_m + \sum_{m=s+1}^{m=n}$$

$$\left(S_m + \frac{M_m}{r}\right) \alpha_s - \left(P_x - \frac{M_x}{r}\right) \alpha_s. \qquad [19]$$

In like manner when the expression for tangential deflection, δ'_s, is set up by use of [1], [6], [7], and [11], there occur terms of the form $U_x\left(n''_s - \frac{m''_s}{r}\right)$ and $U_x n''_m$ which disappear and leave a result which can be written

$$\frac{EI\,\delta'_s}{r^3} = \frac{EI\,\delta\phi_s}{r^2} + \sum_{m=1}^{m=s} \left\{ P_m \int_0^{\alpha_m} \sin(\alpha_m - \theta) \right.$$

$$\cos(\alpha_s - \theta)\, d\theta + S_m \int_0^{\alpha_m} \cos(\alpha_m - \theta)$$

$$\cos(\alpha_s - \theta)\, d\theta - \left(S_m + \frac{M_m}{r}\right)$$

$$\left.\int_0^{\alpha_m} \cos(\alpha_s - \theta)\, d\theta \right\} + \sum_{m=s+1}^{m=n}$$

$$\left\{ P_m \int_0^{\alpha_s} \sin(\alpha_m - \theta) \cos(\alpha_s - \theta)\, d\theta \right.$$

$$+ S_m \int_0^{\alpha_s} \cos(\alpha_m - \theta) \cos(\alpha_s - \theta)\, d\theta$$

$$\left. - \left(S_m + \frac{M_m}{r}\right) \sin\alpha_s \right\}$$

$$+ \frac{P_x}{2} [\alpha_s \cos\alpha_s + \sin\alpha_s]$$

$$+ \left(P_x - \frac{M_x}{r}\right) \sin\alpha_s. \qquad [20]$$

By using [3] for spoke, s, we can write

$$-\frac{1}{2}\frac{B}{B'}\frac{r}{l}\left\{S_s + 2\frac{M_s}{l}\right\} = \frac{EI\,\delta\phi_s}{r^2} \qquad [21]$$

in which $B = \frac{k^2\, l\, EA}{r^3\, E'A'}$ and $B' = \frac{k'^2}{l^2}$. This equation combines conveniently with [14].

If we assume that the inner ends of all spokes descend the same distance, d, we have from the geometry of the figure, since the spoke contracts an amount Δ_s and the outer end moves away from the center an amount δ_s, the relation

$$d = (\Delta_s + \delta_s) \sec\alpha_s.$$

Now when we apply [4] to spoke s,

$$f = -(d \sin\alpha_s + \delta'_s).$$

By [5] $\Delta_s = \frac{P_s\, l}{A'E'}$, so that combining the values of d, f, and Δ_s with [4] we get

$$\frac{-B}{B'}\left\{\frac{1}{3} S_s + \frac{1}{2}\frac{M_s}{l}\right\} = \left(BP_1 + \frac{EI\,\delta_1}{r^3}\right)$$

$$\frac{\sin\alpha_s}{\cos\alpha_1} + \frac{EI\delta'_s}{r^3} \qquad [22]$$

which combines readily with [12] and [13].

Again since d is the same for all spokes, we must have, for $s = 2 \ldots n$,

$$B\,[P_1 \cos\alpha_s - P_s \cos\alpha_1] = \cos\alpha_1 \frac{EI\,\delta_s}{r^3}$$

$$- \cos\alpha_s \frac{EI\,\delta_1}{r^3} \qquad [23]$$

The final equation is that meeting the requirement that the sum of the vertical forces acting upon the rim shall be zero, namely,

$$\frac{1}{2}W + \sum_{m=1}^{m=n} S_m \sin\alpha_m = \sum_{m=1}^{m=n} P_m \cos\alpha_m. \qquad [24]$$

For a wheel of $2n$ spokes, there are for the first position $6n + 2$ unknowns: a moment from each spoke, a shear from each spoke, a thrust from each spoke; also a normal, a tangential, and an angular deflection at the end of each spoke along with the moment M_x and thrust P_x at the highest point on the rim. To determine these unknowns there

are the single equations [13], [14], and [24]; n each of the types [18], [19], [20], [21], and [22], and $n-1$ of the type [23].

The $3n$ deflections may be eliminated from these equations by simple substitution, leaving $3n + 2$ linear equations in as many unknowns consisting of n each of P_m, S_m, and M_m, and one each of P_x and M_x. The unknown thrust P_o and moment M_o at the lowest point of the rim can be obtained by the equations of equilibrium for the half-wheel when the $3n + 2$ other unknowns have been obtained. The formulas for these can be written

$$P_o = \sum_{m=1}^{m=n} \left\{ P_m \sin \alpha_m + S_m \cos \alpha_m \right\} + P_x \qquad [25]$$

and

$$M_o = (P_x + P_o)\, r - M_x - r \sum_{m=1}^{m=n} S_m - \sum_{m=1}^{m=n} M_m. \qquad [26]$$

Equations similar to those we have derived could be set up to determine the shears and moments in the spokes in the second position of the wheel, but these are of such relatively small importance, when compared to the thrust in the vertical spoke in this position, that the labor of solving so many equations would hardly be justified. Therefore, simplified equations only are given for the second position.

SIMPLIFIED EQUATIONS

For the second position of the wheel or in cases where there are several spokes, where the spokes are light compared to the rim or where the spokes are not rigidly connected to the rim the analysis is probably sufficiently accurate if the shears and moments in the spokes are neglected. This greatly reduces the number of simultaneous equations to be solved.

For the first position, neglecting S_m and M_m, we have from equations [13], [14], [18], [23], [24], [25], and [26] the following simplified equations:

$$\sum_{m=1}^{m=n} \left(1 - \frac{k^2}{r^2}\right) P_m \int_0^{\alpha_m} \sin(\alpha_m - \theta)\, d\theta + \pi \left(P_x - \frac{M_x}{r}\right) = 0 \qquad [A]$$

$$\sum_{m=1}^{m=n} P_m \int_0^{\alpha_m} \sin(\alpha_m - \theta) \cos\theta\, d\theta + \frac{\pi}{2} P_x = 0 \qquad [B]$$

$$\frac{EI\,\delta_s}{r^3} = \sum_{m=1}^{m=s} P_m \int_0^{\alpha_m} \sin(\alpha_m - \theta) \sin(\alpha_s - \theta)\, d\theta + \sum_{m=s+1}^{m=n} P_m \int_0^{\alpha_s} \sin(\alpha_m - \theta) \sin(\alpha_s - \theta)\, d\theta + \frac{P_x}{2} \alpha_s \sin \alpha_s + \left(P_x - \frac{M_x}{r}\right)(1 - \cos \alpha_s) \qquad [C]$$

$$B\,[P_1 \cos \alpha_s - P_s \cos \alpha_1] = \cos \alpha_1 \frac{EI\,\delta_s}{r^3} - \cos \alpha_s \frac{EI\,\delta_1}{r^3} \qquad [D]$$

$$\tfrac{1}{2}W = \sum_{m=1}^{m=n} P_m \cos \alpha_m \qquad [E]$$

$$P_o = \sum_{m=1}^{m=n} P_m \sin \alpha_m + P_x \qquad [F]$$

$$M_o = (P_x + P_o)\, r - M_x. \qquad [G]$$

For the second position we will let P be the thrust in the lower vertical spoke and P_n that in the upper vertical one. The half-wheel will, then, be in equilibrium under forces of $\tfrac{1}{2}P$ in the lowest spoke, P_1 in the next, P_2 in the third, etc., and $\tfrac{1}{2}P_n$ in the upper vertical or nth spoke. For this position α_m takes the value $\frac{m\pi}{n}$ and equations [D] and [E] take the forms

$$BP_s + \frac{EI\,\delta_s}{r^3} = BP \cos \alpha_s \qquad [D']$$

and

$$\tfrac{1}{2}W = \sum_{m=1}^{m=n} P_m \cos \alpha_m + \tfrac{1}{2}P. \qquad [E']$$

In the use of equations [A], [B], [C], [D'], [E'], [F], and [G] for the second position wherever P_n would be substituted, it must be replaced by $\tfrac{1}{2}P_n$ in all except [D'].

There is a special case in which the rim is preponderantly greater than the spokes and B becomes large. We may call the case when B is indefinitely great the ideal case for which B approaches infinity. For this ideal case [D] becomes

$$P_s = \frac{P_1 \cos \alpha_s}{\cos \alpha_1}.$$

With this relationship the summations involved in equations [A] to [F] can be evaluated and a general solution obtained. However, B is usually small and the ideal case so impractical that its inclusion here does not seem justified.

Although the formulas given above were derived for a wheel with an even number of spokes, it is evident that the same method of analysis can be used for a wheel with an odd number of spokes.

EXPERIMENTAL VERIFICATION

Verification of the mathematical theory presented above was attempted by the photo-elastic method of stress analysis at the Fritz Engineering Laboratory of Lehigh University. This method of stress determination is applicable essentially to two-dimensional problems. The vehicular wheel, loaded axially, is in a state of plane stress and consequently falls into this category; there are no external forces applied normal to the plane of the wheel and stresses are necessarily limited to this plane.

Photo-Elastic Method. The photoelastic theory hinges upon two basic phenomena, polarization and double refraction of light. By subjecting a bakelite model to circularly polarized light, it is possible to obtain a fringe photograph, such as that shown in Fig. 2. Each fringe represents a definite value of difference of principal stresses (P-Q). The black and white bands are also contours of equal maximum shears, since $(P\text{-}Q)/2$ gives the maximum shear at a point. Black fringes are arbitrarily taken as the bands to be utilized in the photoelastic method.

Stress concentrations prevail wherever the lines are crowded together, such as at a fillet or a point of contact. Advantageous use is made of the fact that one of the principal stresses vanishes at a free boundary. Fortunately, because of this fact, the fringe photograph provides a means of procuring the critical or extreme fiber stresses directly.

The directions of the principal stresses are shown by the stress trajectories of Fig. 3. Plane polarized light is passed through the bakelite model and the crossed Nicol prisms, very essential features of the photoelastic apparatus, are rotated to get the so-called isoclinics, which are lines whose points have the same directions of principal stresses. Having the isoclinic pattern, it is an easy matter to draw the stress trajectories.

Test Specimens. Two bakelite wheels, 3½ inches in diameter and ¼-inch thick were made. One had four ¼-inch spokes and a ⅜-inch rim; the other had six 3/16-inch spokes and a ¼-inch rim. Each had an axle hole ¼ inch in diameter and a hub ¾ inch in diameter. The existence of so considerable a hub made the models differ some from the theoretical wheels, but this condition was partly provided for in the distinction between the radius, r, of the rim and the length, l, of the spokes.

For the purpose of finding the value of the differences of principal stresses represented by the fringes, a calibration beam was cut from the same piece of bakelite as the wheel and was subjected to identical annealing conditions with the test models. The beam was tested in pure bending, whereupon recourse was had to the well-known beam formula in finding the fringe coefficients.

In addition, two rubber wheels, having the same dimensions as the bakelite models, were cut out with a view to finding the type of stress at various points of the boundary. To facilitate this qualitative analysis, slits about 1/16 inch in depth were made along the entire boundary. Axial load was applied with the spokes in the positions being studied; opening of the slits indicated tension, whereas closure pointed out regions of compression. The points where the type of stress changes on the rubber specimens were remarkably close to those in the case of the photoelastic models.

The load was applied axially to the wheel by a steel snugly-fitted roller which supported steel wires on either side of the model. A special loading rig was connected to the wire loops, and desired amount of dead weights was placed on the loading pan.

Four-Spoked Wheel. POSITION 1. For the first position, with the two lowest spokes making equal angles with the vertical equations [13], [14], [18], [19], [20], [22], [23], and [24] of the mathematical analysis were solved in obtaining the following values for thrusts, moments, and shears:

$P_1 = 0.0544W$ $\quad S_1 = -0.3610W$ $\quad M_1 = 0.1942W$
$P_2 = -0.1362W$ $\quad S_2 = -0.1555W$ $\quad M_2 = 0.0594W$
$P_x = 0.0263W$ $\quad M_x = -0.0461W$

By equations [25] and [26]

$P_o = 0.1768W$ $\quad M_o = 0.3233W$

When we use the simplified equations [A] to [G], we get

$P_1 = 0.5197W$ $\quad P_o = 0.2273W$
$P_2 = 0.1875W$ $\quad M_x = -0.0950W$
$P_x = -0.0076W$ $\quad M_o = 0.4386W$

These results differ radically from each other, but on the critical value, M_o, the error in the simplified solution is on the side of safety.

Using the results obtained in the general solution, it was possible to determine the border fiber stresses shown in Fig. 4. Rim stresses were plotted radially, while the spoke stresses were measured perpendicularly to the axis. Dotted lines indicate compression, full lines tension. There is lack of continuity at the juncture of the rim and spokes, but this is accounted for by the fact that the theory was developed on the assumption that the spokes were lines and the rim a circle.

Boundary fiber stresses obtained by the photoelastic method are shown in Fig. 5. Comparison of this figure with the former shows some disagreement both in type and magnitude of stress, with the analytical values on the side of safety. There is fair agreement, however, in the critical values. Concentrations of stress prevail around the fillets as is indicated by the photoelastic results. It is common knowledge that stresses generally decrease with increase in size of fillet. The critical stress to be used in the design of the rim is found at the lowest section. The rim should, therefore, be designed to stand a moment M_o and the spoke a moment M_1 as determined for this position.

POSITION 2. With two spokes vertical, since the moments and shears in the spokes are small, we use the simplified equations [A], [B], [C], [D'], [E'], [F], and [G]. When the resulting simultaneous equations are solved, we obtain

$P_1 = -0.0762W$ $\quad P_x = 0.0381W$ $\quad P_o = -0.0381W$
$P_2 = -0.0918W$ $\quad P = 0.9182W$ $\quad M_o = -0.0532W$

Thus the lower vertical spoke is seen to take 92 per cent

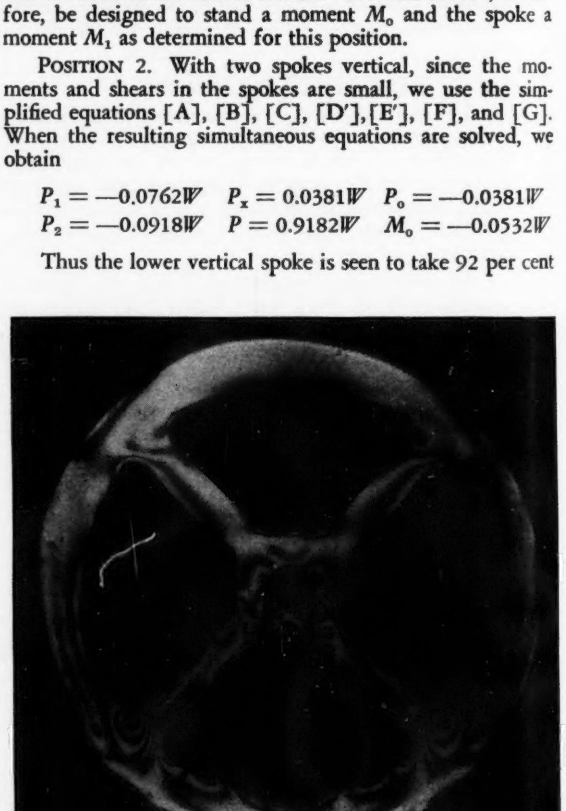

FIG. 2 A FRINGE PHOTOGRAPH OBTAINED BY SUBJECTING A BAKELITE MODEL TO CIRCULARLY POLARIZED LIGHT

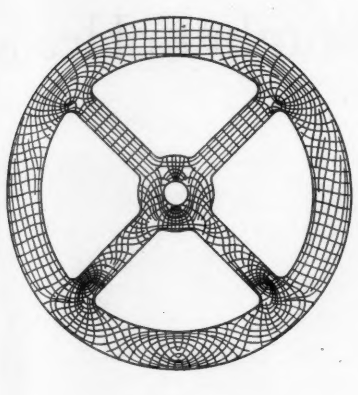

FIG 3

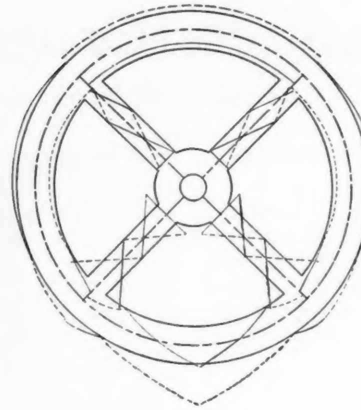

FIG 4

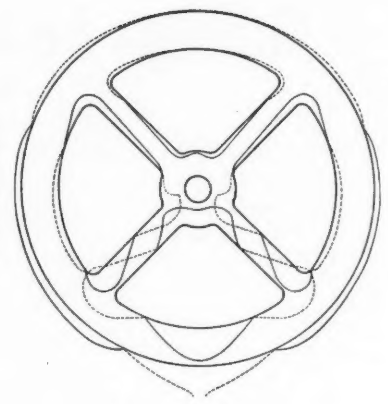

FIG 5

FIG. 3 STRESS TRAJECTORIES. FIG. 4 ANALYTICAL BORDER STRESSES. (BROKEN LINES INDICATE COMPRESSION; SOLID LINES, TENSION.) FIG. 5 PHOTOELASTIC BORDER STRESSES. (BROKEN LINES INDICATE COMPRESSION; SOLID LINES, TENSION)

of the load, so that the spokes must each be designed to carry the whole load in compression. By the photoelastic method it was found that 93 per cent of the total load was taken by the lower vertical spoke. It should be noted that these values apply to the wheel tested. For wheels of other dimensions the results would naturally be different.

Six-Spoked Wheel. A study of the 6-spoked wheel confirmed the deductions drawn for the 4-spoked wheel. Experimental results showed relatively low stresses in the upper half of the wheel for the first position with spokes at 30 and 90 degrees to the vertical. Design precautions similar to those in the case of the 4-spoked wheel should be noted here. The first position gives the criterion for maximum rim stress. With two spokes vertical the major portion of the load, here too, is carried by the lower vertical spoke. Analytical results were again on the safe side.

Acknowledgment. The mathematical analysis presented in this paper was developed by Professor Reynolds and the photoelastic verification was attempted by his co-author. The authors are indebted to Professor Inge Lyse and Mr. D. M. Stewart, both of the Fritz Engineering Laboratory, for their invaluable suggestions and assistance in the experimental part of the investigation.

SUMMARY

Epitomizing, the following deductions may be made regarding the axially-loaded spoked vehicular wheel:

1 The mathematical theory of elasticity was utilized in developing general and simplified methods of analysis for vehicular wheels with an even number of spokes.

2 Critical rim and spoke moments are developed with the two lowest spokes of the wheel assuming an equal angle with the vertical.

3 When two spokes are vertical, the lower spoke takes over ninety per cent of the load; it is desirable, therefore, to design spokes so that they will carry the entire load in this position.

4 Both the analytical and photoelastic results confirm the fact that the two lower spokes of the four-spoked wheel, with spokes at 45 degrees, develop higher stresses than the upper spokes. This is contrary to the opinion of a former investigator.

5 The upper half of the 6-spoked wheel in both critical positions had relatively small stresses.

6 Although there was some lack of agreement between the analytical and experimental results, the critical conditions which are most important from the practical viewpoint were approximately similar, with the analytical solution practically always on the safer side.

7 It is felt that the graphical method of analyzing stresses in this problem leads to erroneous results. The present investigation takes into account the elasticity of straight and curved rods, and as a consequence approaches actual stress conditions more closely.

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A Thresher for Individual Grain Sorghum Heads

By M. H. Byrom and H. P. Smith

THE DIVISION of agricultural engineering of the Texas Agricultural Experiment Station, at the suggestion of Frank Gaines, has built a small machine to thresh and clean grain from individual heads of grain sorghum. Fig. 1 shows the machine set up for single heads, but several heads can be threshed at a time by changing the trash shoe and auxiliary cleaning funnel. Wheat and oats probably could be threshed by adjusting the concaves closer to the cylinder.

The machine is designed to prevent grain from spitting back out of the feed hopper and grains from lodging in corners and on projections inside the housing about the cylinder and concaves. The machine thoroughly cleans itself after each head is threshed. It is also adjustable, compact, and sturdy.

The cleaner consists of a large funnel 30 inches long with a diameter of 16 inches at the large and 6 inches at the small end. A 6-inch pipe 12 inches long forms an extension for the small end. A slotted baffle or grill is installed near the center line of the cleaner funnel and parallel to it to control the movement of the grain.

In operation the grain head is inserted through the round hole in the feed hopper cover (Fig. 2) until the head passes between the cylinder and the concave rasps. By slightly rotating the head, all of the grain is removed. The bottom of the feed hopper is small enough to prevent injury to the hand holding the stem of the grain head. After the grain is threshed, the stem is either withdrawn or permitted to pass under the cylinder into the trash shoe, where it is caught on the one-fourth-inch mesh hardware cloth. The shoe can be slipped off and the stem and other large trash removed. The threshed grain passes down the spout, through the hardware cloth in the trash shoe, and into the small cleaner funnel. It then falls through the small slot in the side of the air funnel over a lip baffle and onto a slotted baffle, which permits the grain to pass downward through the slots, at the same time retarding its speed so that when it reaches the lower side of the air funnel, it will gently roll down the sloping surface into a box under the bottom edge. A blast of air, created by an electric fan, blows the small chaff out the small end of the funnel.

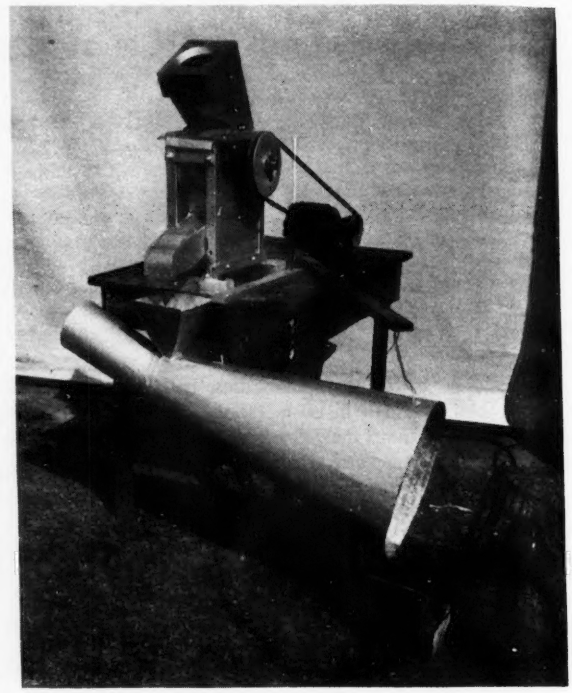

FIG. 1 SINGLE-HEAD GRAIN SORGHUM THRESHER SET UP FOR OPERATION

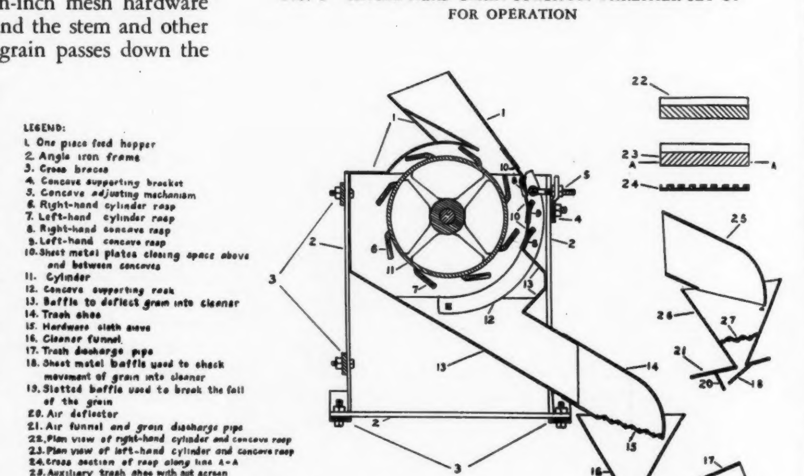

FIG. 2 CROSS-SECTION OF SINGLE-HEAD GRAIN SORGHUM THRESHER AND CLEANER

Authors: Respectively, assistant agricultural engineer (Assoc. Mem. ASAE), and chief, division of agricultural engineering, Texas Agricultural Experiment Station. (Mem. ASAE.)

Agricultural Engineer — Technician or Engineer

Agricultural Structures

By Harold E. Pinches

THE PLACE of farm buildings as a factor in agricultural production can hardly be overstated. Their importance was set forth by a Roman writer over two thousand years ago: "In his youth, the farmer ought, diligently to plant his land, but he should ponder before he builds. Planting does not require reflection, but demands action. It is time enough to build when you have reached your thirty-sixth year, if you have farmed your land well meanwhile. When you do build, let your buildings be proportioned to your estate, and your estate to your buildings." (Cato: "De Agricultura"). The same writer is quoted as advising "to buy what others have built rather than build oneself, and thus enjoy the fruits of another's folly."

The same considerations hold true today. A very recent study, that of the USDA Bureau of Agricultural Engineering in its project "Engineering Reorganization of Farms," has found the buildings on many farms to be badly out of balance with the farm. "Buildings are frequently unadapted to the purpose for which they are used and the location of new buildings is often determined by the availability of space rather than convenience. . . . . Where the reorganization plan is based on a change in the type of farm business, the buildings may require considerable alteration. This happens to be true of a number of farms studied in the Ohio project." (N. A. Kessler before the ASAE annual meeting, June, 1935).

"In that state (Ohio) the value of the farm buildings is comparatively high, sometimes exceeding the value of land. Under such circumstances it is evident that the equipment represented by the buildings is one of the most important factors in determining the farming program and the extent of production in certain lines. However, many of the buildings were erected some years ago when the farming program was entirely different from what it is now and consequently are unsuited for the present needs of the farm." (Report of the Chief, USDA Bureau of Agricultural Engineering, 1935.)

While such generalizations about the importance of farm buildings may be granted easily, we should go farther in a consideration of the agricultural engineer's job as related to farm structures.

According to Kessler, the object of the Bureau of Agricultural Engineering project, "which has been called the Engineering Reorganization of Farms, is to determine the needs of individual farms for engineering improvements and the benefits which will be derived from their application." This is, obviously, a worthy project if it means what it might; at least, it is a start in the right direction. In so far as it helps the individual cooperator, it probably will be appreciated but will be expensive help.

But there is a difference between farm management—helping to better organize an existing farm—and agricultural engineering. To get far toward setting up a program for management of agriculture on a basis of engineering principles, requires that those principles first be established. In fact, it is difficult to see how engineering can go very far on a sound footing in the reorganization of even an individual farm, until some fundamental principles have been set up at least tentatively. An engineer may keep himself busy and valuable helping to redesign outmoded buildings. We have such a problem here in Connecticut with our redundant tobacco barns. Or he may improve contemporary designs. In either case he will be a technician. There is a bigger job to be done, that of presenting agricultural structures on a basis that is worthy to be called engineering.

The fundamental approach that needs to be made is to start out by separating, temporarily, structures from the farm and from field production. There need to be carried on several thorough and far-reaching functional studies of structures to penetrate through tradition and custom. There is, of course, much that is sound and reasonable behind contemporary building practices, but there are also many impedimenta from earlier thinking or conditions.

The way that older conditions may influence modern practices is illustrated by the Swiss land measure, the "morning". A "morning" was originally the amount of grass land that a man could mow in a morning. This unit will doubtless persist long after other methods of grass harvest have come and gone to be replaced by still others. Similar influences can be discovered as having determined many contemporary building practices.

There is good reason, and the weight of a vast amount of practical experience, behind the closely standardized width of modern dairy barns. But sufficient study of dairy barn functions might long ago have raised, and answered otherwise, the question "Is the best way to handle dairy cows that of tying them up in two lines face to face or tail to tail?" Some new methods are showing promise—not methods that had to wait upon discovery of materials or invention of equipment but upon thinking.

GETTING DOWN TO PRINCIPLES

Many other illustrations could be given to show the way in which single, noncoordinated premises have imposed themselves upon structural design. The emphasis some years ago on the germicidal value of light led to buildings with many glass windows, by which the low value of winter light was thoroughly filtered out. Emphasis on "fresh air" swung the pendulum too far in many ventilation practices. How voluminous is the literature on design of several types of self-supporting roofs to enclose vast hay storages over the dairy; comparatively, how meager is the discussion (until very recently) on the problem of hay storage as related to building design, quality of the product, labor requirements, and fire protection.

The procession of types of poultry houses which have been fostered as the ". . . State Poultry House" are a monument to the adaptability of the hen but not so surely to farm buildings engineering. The only reason for a poultry house, as for a factory, is to provide certain artificial conditions—conditions limited by several factors including optimum conditions for the hens and for the operator, eco-

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This is the second article in a series further developing the implications of the author's editorial, entitled "What is the Agricultural Engineer's Job?" published in AGRICULTURAL ENGINEERING for December 1935.

Author: Assistant professor of agricultural engineering, Connecticut State College. Mem. ASAE.

nomic considerations. How much is known about optimum conditions for hens? The current discussion on free ventilation vs. restricted ventilation, heated vs. unheated houses is certainly concerned with fundamentals that should precede much designing of structures. How much thought has been given to labor efficiency and operator's comfort? A detailed study of one ". . . . State Poultry House," on the State University Farm, which I made a few years ago, showed an amazing amount of pure pedestrianism—preventable pedestrianism—imposed by the building design and layout.

An argument was started some years ago about our "modern dairy barns" which was not carried far enough. One engineer stated (AGRICULTURAL ENGINEERING for September 1927) that he believed "that dairying is working under a design which, while being called 'modern', should be considered hereditary." He raised the question as to whether so-called "modern two-story barns are 'worth their cost, in terms of economical production, improvement of working conditions, or in aesthetic value to the farmstead.' Similar questions were asked concerning the other buildings usually associated with farming. He then said, "It is patent that industry generally could not stand the present overhead which is being carried by agriculture."

He was answered by a representative of one of the companies manufacturing barn equipment with a somewhat different set of figures, which indicated that for better-than-average cows the overhead cost of modern dairy barns was not too high (AGRICULTURAL ENGINEERING for January 1928). While this was a refutation of part of the claims originally advanced, it dodged the fundamental question of whether overhead costs due to buildings could be reduced while maintaining functional efficiency.

CONTROLLED CONDITIONS

It may not be easy to determine just what "artificial conditions" a farm building needs to provide. It may be that the economic limitations on design are severe. It may be that the most desirable buildings, from the engineer's viewpoint, cannot be supported by the average farm. These difficulties only indicate more clearly the need of functional studies of agricultural structures. Design is secondary and a means to an end.

There is need for more controlled studies (1) to discover scientific bases for ventilation, lighting, optimum temperatures and humidities, and comfort limits (consider the wide variation between the premises on which some of our standard systems of dairy-barn ventilation are set up); (2) to discover fundamental size and shape relations (as dairy barn width for two rows of stanchions is well known); (3) to discover relations of labor efficiency to building layout.

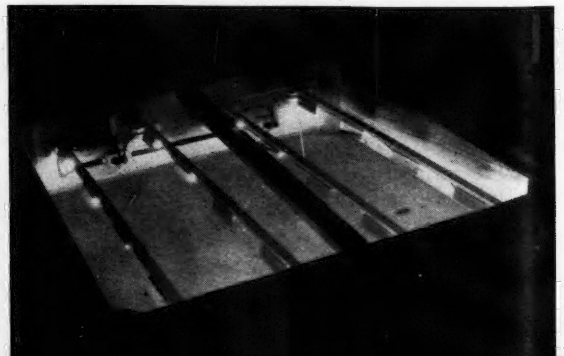
There is need for more emphasis on adaptability and unit sizes and shapes. The report of the Bureau of Agricultural Engineering on reorganization of farms cites a case in which one farm had a large barn in which a number of horses were kept formerly. It seems that the best thing to do now is to rebuild that barn for a poultry house. The builder of that barn probably never anticipated that horses would not be kept on that farm; but the engineer should count on the possibility of change as one of the most important design characteristics. Agriculture throughout the country is changing too rapidly to justify "freezing" any building in one mold more rigidly than necessary.

One writer has urged the economy and desirability of buildings that will last a hundred years. But is any building now one hundred years old not obsolete? Can any design, even based on the best of functional studies, anticipate enough of the likely changes of the next hundred years? Must we not take seriously the possibility of large use of prefabricated, sectional buildings, which will permit function, layout, even location, to be changed?

If similar structures can be designed for specific farm-building needs, buildings "buttoned up the front and down the back," changes can be made more easily to meet farm and regional production shifts. The horse barn referred to earlier will doubtless become a satisfactory chicken house, with sufficient rebuilding. But why not build so that a certain combination of units is a horse barn; a certain combination of some of the same units is a chicken house, and the specialized units, such as mangers, can be salvaged as units instead of scrap lumber. Consider how much less the buildings would then impose a fixed system of farming on a certain area of land. Instead of buildings standing a hundred years, they would stand only so long as they served useful ends; then they would be taken apart and their members reassembled, perhaps miles away, in other forms. Mistakes could be rectified instead of being suffered. Needless duplication of partly used structures could be measurably reduced.

Perhaps the basic question, from which these other considerations spring, is this: Are farm buildings a place in which to do chores, which are incidental to the main business of the farm; or are they the scene of certain manufacturing processes—not only the scene, but implements in the process? Let them be separated—for the sake of study—from field production. Let the building's function, and the economic limits of that function, determine fundamental designs. The adaptations of these designs to individual farms can come later.

The work outlined here is not for the engineer alone. As I said in the preceding article on farm machinery, "No single or simple set of principles of mechanics could furnish the basis for such a program. Nor would such a program be the work of professional agricultural engineers alone." Functional buildings must be built on more than mechanics. There will need to be coordinated the knowledge and technical skills of many fields, including structural engineering; some of the sciences of animals and crops; industrial management, for what it can tell of the technic of plant layout; air conditioning, with its ramifications in heating, ventilation, refrigeration, and structural materials. Of such will truly engineered agricultural structures be made.



GREENHOUSE BENCHES WIRED FOR PROPAGATING AZALEAS. GREENHOUSES, WITH THE AID OF ELECTRICITY, CREATE AND CONTROL CONDITIONS OF TEMPERATURE, LIGHT, VENTILATION AND SOIL TO MEET CLOSELY DEFINED REQUIREMENTS OF SPECIAL CROPS

Aerial Surveying for Measuring Fields

By O. J. Marshall

AS AN EXPERIMENT in measuring AAA commodity fields, Preble County, Ohio, was mapped by aerial photography in August 1935. Field areas were scaled from enlarged prints by planimeter. The results, as reported in a civil engineering thesis by C. S. Coblentz, indicate consistent accuracy beyond the requirements accompanied by a definite saving in costs.

An overall check on the accuracy of this method was obtained by checking the scaled area of 19 fields picked at random with the area found by a transit and tape survey of each of the check fields. Fields of various sizes were chosen so that the resulting report on accuracy would have general application. Four of the fields were over 20 acres, the rest under 10 acres, and seven of them under 5 acres. The largest error in area was 0.15 acre in a field of 21.7 acres, although two fields were larger than this. The probable error of the area of any one field, as determined from the results of those fields under 10 acres, was 0.037 acre.

The experiment was conducted in an agricultural country having some 3,000 AAA contracts for all commodities. The cost of the photographing, enlarging, indexing, and filing, as hereafter explained, was divided among the various county associations. The following cost figures, although applied to the measurement of corn only, are typical of all commodities:

COST OF MEASURING CORN ON 1071 FARMS

	Average cost per farm
Measurement by ground traverse methods, 1934	$1.88
Measurement by aerial mapping, 1935, including share of costs of photographing, enlarging, indexing, and filing	1.44
Measurement by scaling from enlargements which have been indexed and filed—estimated future annual costs for field identification and computations only	.76

These figures indicate a saving of 23 per cent of the original cost in the year when the photographs are taken. Then an estimated 53 per cent of this cost will suffice for each succeeding year.

Aerial Photography. The contract for taking the photographs, submitting contact prints to the engineer for determination of enlargement ratio, and making one enlarged print of each was let on a lump-sum basis. The contractor, after a study of general topography, as shown by USGS topographic sheets, and due consideration of the purposes of the survey, made up his plan of procedure, known as a "flight map." This indicated 17 flight lines running alternately east and west across the county 1½ miles apart. Using a camera with single lens of 10-inch focal length and flying at 13,000 feet above the ground surface resulted in a scale in which 1300 feet was represented by 1 inch (approximately) on the contact prints. The sidelap of prints was 30 to 40 per cent, and 25-second intervals between photographs produced an overlap of 50 to 60 per cent.

Control Surveys by Automobile. The contemplated use of any control survey is, or should be, the chief consideration when planning the surveying procedure. An economical survey is designed to obtain the required accuracy and no more. In determining the scale of contact prints on this project, by comparing scaled distances with actual field measurements, an error of 0.01 inch in the comparison was assumed. This corresponds to an error of 13 feet on the ground. Using an odometer on the front wheel of an automobile to count the revolutions, and marking the tire to read in tenths of a revolution proved to be an economical procedure by which lines up to a mile in length could be measured within 10 feet. To carefully calibrate the wheel several variations in air pressure and speed of the car were tried over a measured course, resulting in the adoption of 55 pounds per square inch air pressure and a speed of 15 miles per hour as giving the most consistent calibration. Separate calibrations were made for gravel and hard-surface roads.

Some 500 miles of control lines, averaging about a mile in length, were measured by this process, the lines running between points easily identified on the photographs. These measurements were used to supplement the information obtained from records of the state highway department and the Ohio topographic survey.

Problems of Scale and Enlargement. In general the two main factors causing variation of the scale within an aerial photograph are changes in ground elevation and tilt of the camera. On this particular job the tilt was held under 1 degree for 99 per cent of the photographs, and always well under 2 degrees, so no allowance for tilt was necessary in determining scale with sufficient accuracy for the purpose.

The changes in ground elevation were included as a factor in the determination of the scale of each contact print by comparison with the known distances provided by the control survey. This method of direct comparison was used to establish the scale ratio of the majority of the prints. Where no measured line appears on the print the usual procedure has been to "step" the scale across one or more prints using the overlapping portion as a basis. However, investigation showed that the absolute elevation at which the plane was flying could be determined with considerable accuracy by taking approximate elevations of control lines from USGS topographic sheets and using the well-known relation that scale ratio is proportional to f/H, in which

f = focal length of camera lens
H = height of camera above ground surface.

Flight elevations thus determined from various prints on a flight line showed the average variation to be less than 20 feet. A procedure based on this principle proved very satisfactory for determining the scale ratio on those prints where no direct control was available.

Tables were then prepared showing the scale of each contact print and the elevation, to the nearest 20 feet, of the major portion of the terrain. From these tables an enlargement ratio was figured for each print which would give a scale of 400 feet equals 1 inch on the enlargement print for areas at the elevation of the major part of the terrain.

A table was then prepared showing number of acres per square inch for various elevations according to scale of the enlargement. Field areas were calculated by multiplying the proper factor taken (Continued on page 184)

Author: Assistant professor of surveying and geodesy, Ohio State University.

The Division of Structures (BAE, USDA)

THE work of the Division of Structures Bureau of Agricultural Engineering, U. S. Department of Agriculture, began in 1914, and at that time consisted of surveys of farm building conditions in various parts of the country and of the preparation of building plans to meet the requests of farmers. It soon developed that extensive research work was necessary in order to obtain the fundamental information necessary for the development of economical structures and this phase of the work has gradually grown until it is now the major part of the division's activities. Wallace Ashby has been chief of the Division since July 1931.

Work under the project title "Farm Houses" is handled directly by Mr. Ashby with the assistance of T. A. H. Miller. The general purpose of this project is to improve the living conditions and the economical construction of farm homes. The Washington office is generally recognized by other federal and state agencies as the center of information on rural housing. In 1934 the Bureau cooperated with the Bureau of Home Economics, the Extension Service, and forty-six state agricultural colleges in the farm housing survey, a relief project, which developed a mine of information as to rural housing conditions and considerable information on recent developments in farm housing practice in various sections of the country. Two recent bulletins, "Farmhouse Plans" and "Modernizing Farm Houses," based in part upon the results of this study, have been issued. A field study of farm housing in cooperation with the department of agricultural engineering of the University of Wisconsin has recently been initiated. The object of this work is primarily to make farm homes more comfortable. A detailed study is being made of temperatures, humidity, drafts, and natural and artificial lighting in farm houses of different designs and materials. When the optimum conditions of these various elements of living comfort and convenience are determined, building plans to provide them in an economical way will be prepared. The study in Wisconsin will be duplicated by a similar project located in one of the southern states where summer heat, rather than winter cold, is the probable determining factor in designing for comfort. Work in the South will include studies of the effects of ventilation and ceiling heights upon comfort, and of the location of doors and windows on light and ventilation, and of the use of insulating materials.

COOPERATIVE STUDIES

Under the project, "Buildings for Livestock," M. A. R. Kelley is preparing a technical report on the study of the relation of air conditions in dairy barns to milk production. This study is cooperative with Brook Hill Farm, the University of Wisconsin, and the Bureau of Dairy Industry of the U. S. Department of Agriculture.

Three work projects are being carried on under the title "Buildings for Farm Products." The work on white potato storage problems under A. D. Edgar, in cooperation with the Maine Agricultural Experiment Station and the Bureau of Plant Industry, is directed toward the design of potato storages which will (1) keep potatoes safely with little loss in quantity or condition, (2) require the minimum amount of labor and expense in handling the crop into and out of storage, and (3) be subject to minimum depreciation losses. This project has been under way in Maine for some years and is nearing completion.

The second subproject, "Grain Storage," is carried on with regular Bureau funds by Mr. Kelley and J. R. McCalmont. In the past it has dealt with surveys of grain storage which were the basis for Farmers' Bulletins No. 1636, "Farm Bulk Storage for Small Grains," and No. 1701, "Corn Cribs for the Corn Belt." More recent work includes the measurement of pressures in corn cribs which is now being carried on in cooperation with the department of agricultural engineering of Ohio State University.

WHEAT STORAGE

The subtitle "Wheat Storage" covers a new project which is financed by special research funds provided for the Department by the Bankhead-Jones Act and is cooperative with the Bureaus of Agricultural Economics and Plant Industry and the state agricultural experiment stations of Illinois, Kansas, and North Dakota. The object of this project is to determine the optimum conditions for the storage of wheat on farms over considerable periods of time. It is expected that a series of six to ten full-sized grain bins and eight to twelve miniature bins will be constructed in each of the cooperating states and at the Arlington Experimental Farm in Virginia. The types of granaries constructed will include those commonly used by farmers as well as experimental designs. The bins will be so equipped as to make possible studies of the effects of varying moisture content, solar heat, day and night temperatures, atmospheric humidity, and methods of ventilation upon the stored wheat. Temperature changes in the wheat will be closely observed by use of thermocouples located in the mass of wheat and at critical locations on the bin surfaces. More complete information on the changes taking place in the wheat will be obtained by sampling it at the time it is placed in the bins and at frequent intervals thereafter. The samples collected will be tested according to the standard methods developed by the USDA Bureau of Agricultural Economics for moisture content, grade, per cent dockage, per cent damage, and other grade-factor data. In addition to these data, observations will be made of the germinating quality of the stored wheat and of the presence of bacteria and mold fungi. In cases where the wheat has gone out of condition during storage, data will be obtained with respect to degree of rancidity and milling and baking properties. Data on insect infestation and damage will also be obtained. In other words, efforts will be made to obtain very complete information on the changes in market and milling values of the wheat during the storage period as influenced by the quality and condition of the wheat at the time it was put into storage and by the type of grain bin. This work will be supplemented by observations of storage conditions in farm granaries. It is planned that in each of the cooperating states arrangements will be made with at least twenty-five farmers to sample the grain stored in their bins so that substantially the same data may be obtained as in the case of the experimental bins. It is thought that the data obtained from these experiments will furnish the information necessary to permit the design of safe and efficient buildings for the storage of wheat on the farm. This project is under Mr. Ashby's direction with the assistance of C. F. Kelly.

The project "Equipment and Facilities for Farm Buildings" under the direction of A. H. Senner includes studies of greenhouse heating, use of steam in the sterilization of soils, and tests of oil-burning equipment. A study of bottled gases for use in cooking, water heating, etc., is now under way in cooperation with the National Bottled Gas Association and the Bureau of Home Economics. The easily condensed components of natural gas which were formerly wasted are now rapidly finding new uses in farming areas where piped gas is not available. Recent reductions in the prices of the necessary equipment are bringing the use of this gas within the reach of many farm people. The studies now under way will yield information on comparative costs of this and other fuels and on its effectiveness in food preparation. Under this project heading comes the work on farm water supply, plumbing, and sewerage, which is under the direction of George M. Warren. The Bureau's bulletins on these subjects are familiar to many agricultural engineers and are among the Department's "best sellers."

STORAGE IN TRANSIT

The project "Temperature and Humidity Control in Protecting Farm Produce in Transit," carried on by W. V. Hukill and S. J. Dennis, is largely in cooperation with the Bureau of Plant Industry. Recent work relates chiefly to the use of refrigerator cars for the transportation of apples and pears from the West Coast during cold weather when the fruit must be protected from freezing, and the transportation of citrus fruits and vegetables from southern and western sections during warm weather when refrigeration is required. Studies have also been made of the shipment of citrus fruits by boat through the Panama Canal, the use of refrigerator trucks for handling perishable products, and the precooling of perishables before shipment. The necessities of this work resulted in the development of a number of new and exceedingly delicate instruments such as the remote-reading thermocouple anemometer used for obtaining rates of air circulation and a very delicate calorimeter for measuring the heat of respiration of fruits and vegetables. The work already done under this project has resulted in many improvements in refrigeration practices and consequently is proving of benefit both to grower and shipper.

In addition to its research work the Division is taking an active part in building up the regional plan exchange services in which it has been acting as a clearing house for the exchange of building plans for farm structures among the state agricultural colleges. By means of this service transparent brown-line prints of many types and kinds of farm buildings are furnished to the states which in turn furnish blueprints made from *(Continued on page 167)*

The Joint Committee on Fertilizer Application

NO SPACE need to be taken to explain why the science of fertilizer application is an extremely complex subject invading several branches of agricultural science and demanding considerable research in each.

To foster closer cooperation between these branches, and to institute some needed joint studies, the National Joint Committee on Fertilizer Application was formed in 1925 at the suggestion of Dr. Lipman of New Jersey. At the first meeting, sponsored by the National Fertilizer Association, E. V. Collins represented ASAE, and the National Association of Farm Equipment Manufacturers (now the Farm Equipment Institute) was represented by C. H. White of Deere and Company.

Early general chairmen were Director Haskell of NFA, and Dr. Truog of the University of Wisconsin. O. V. Jensen, then with NFA, was the first general secretary. Under the able leadership of these men, the Joint Committee enjoyed a good start, and its ten years of painstaking effort have resulted in an enviable record of achievement accelerated during the past two years by the recent general chairman, R. M. Salter, and by the present general secretary, Dr. H. R. Smalley, who received the hearty support of all of the parent sources of membership in pushing forward important work on fourteen different crops.

As may be inferred from the accompanying chart, each of the five national organizations composing the "parent sources of membership," has its own fertilizer committee responsible for activity within its own field. These committees automatically become members of the Joint Committee, and the five chairmen, together with the general chairman and the general secretary of the Joint Committee, form the advisory board. At present the members of this board are:

- C. O. Reed, Ohio State University, general chairman
- H. R. Smalley, National Fertilizer Association (Washington, D. C.), general secretary
- G. A. Cumings, Bureau of Agricultural Engineering, representing ASAE
- R. M. Salter, Ohio State University, president of and representing ASA
- H. H. Zimmerley, Virginia Truck Experiment Station, representing ASHS
- H. B. McKahin, Deere and Company, representing FEI
- F. E. Bear, American Cyanamid Company, representing NFA.

Inasmuch as the advisory board is the coordinating agency, it becomes the heart of the organization. Into it come all proposals, and from it go suggestions for delegation of activity. Upon its judgment depend recommendations for needs and for ways and means of maintaining balance in the national fertilizer program. It must collect and coordinate results, and from its vision must come inspiration and guidance.

Much progress has been made in the manufacture of fertilizers; but there are many things yet to be determined for greater efficiency in the application of the six million tons of commercial fertilizer which this country uses annually. The use of these materials is very definitely involved in the nation's land utilization program. Experiments are being conducted in at least twenty-two states; some of these are in conjunction with and others are in addition to the extensive work being carried on by federal bureaus. Thus the Joint Committee not only has a definite responsibility, but also it is a good example of organization set-up to foster cooperation and to promote coordination within a realm of complexities.

To work intensely within areas which can be defined rather definitely, the Joint Committee has its own subcommittees, each composed of one member from each of the five parent organizations. Mr. Smalley is chairman of the subcommittee on publicity, which includes educational and extension activity; and Mr. Cumings is chairman of the subcommittee on machine application and placement.

Most of the "cooperating organizations for practical results" are represented in the Joint Committee through the five national societies. The success of the work has depended in no small way upon the loyal support of the manufacturers of fertilizer handling machinery, and upon the many courtesies of the National Fertilizer Association which has supported publications and which arranges for the annual meeting usually held in November in either Washing or Chicago.

Special mention also should be made of the great amount of work accomplished by federal bureaus. The Bureau of Chemistry and Soils and the Bureau of Plant Industry have made marked contributions not only from their own extensive work and publications, but also by their generous cooperation with state agencies and through the national societies. The Bureau of Agricultural Engineering, through Messrs. McCrory, Gray, and Cumings, always has been active in its support of Joint Committee activity, and Mr. Cumings now is the hub around which spins much activity of major importance in the Committee's work. Since 1931 the Bureau has expended more than a hundred thousand dollars in its cooperative work with the Committee and with state experiment stations. A number of experimental machines have been built to point the way toward better fertilizer practices, and at Arlington Farm the Bureau has the country's finest laboratory for fertilizer machinery studies.

The full membership of the two committees from the parent organizations of most direct concern to agricultural engineers are:

ASAE Committee on Fertilizer Placement

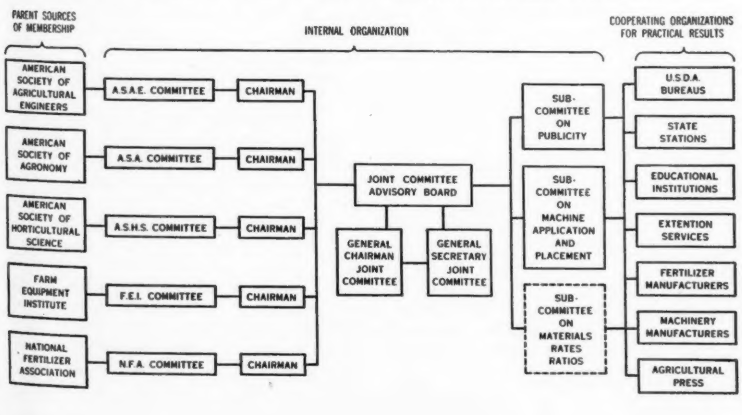
- G. A. Cumings (chairman)
- C. J. Allen
- E. V. Collins
- E. R. Gross
- C. O. Reed
- H. P. Smith
- J. O. Smith
- C. H. White

FEI Committee on Fertilizer Distribution Machinery

- H. B. McKahin (chairman)
- F. H. Bateman
- P. R. Borman
- H. B. Dineen
- B. B. Hathaway
- D. C. Heitshu
- C. H. Zirckel.

This year additional recognition and responsibility has come to the American Society of Agricultural Engineers by the election of C. O. Reed as general chairman of the Joint Committee, after he served several years on the Society's own committee.

ORGANIZATION CHART OF THE NATIONAL JOINT COMMITTEE ON FERTILIZER APPLICATION



The Division of Structures

(Continued from page 166)

the brown-line prints to farmers, usually at the cost of printing and handling. At first this exchange handled only drawings prepared in the Division, but it has been broadened to include plans prepared in the various states and a selected set of drawings covering a wide range of buildings is now included in the exchange.

When the Midwest Farm Building Plan Service was organized, some 3200 brown-line prints were furnished to it and to date a total of 7200 brown-line prints of various farm building structures have been supplied to state agencies. The Division, with the cooperation of S. P. Lyle, is now working with the twelve northeastern states in the selection of drawings to be included in the Northeastern Farm Building Plan Exchange and in the preparation of a catalog of those plans.

NEWS

PROVISIONAL PROGRAM

30th Annual Meeting of the American Society of Agricultural Engineers
Stanley Hotel, Estes Park, Colorado—June 22 to 25, 1936

SUNDAY, JUNE 21

2:00 to 8:00 p.m.—Registration, Stanley Hotel Lobby

2:00 to 6:00 p.m.—Council Meeting

MONDAY, JUNE 22

8:30 a.m. to 12:30 p.m.—(Three concurrent sessions)

I—*College Division*
Presiding: R. H. Driftmier, division chairman

II—*Committee on Extension*
Presiding: H. H. Sunderlin, committee chairman

III—*Student Group*
Presiding: Paul Doll, president, National Council of ASAE Student Branches

2:00 to 5:00 p.m.—(Informal activities)
Committee and group conferences, trips, etc.

8:00 to 10:00 p.m.—(Informal activities)

1 Illustrated lecture on Rocky Mountain National Park
2 Group round tables

TUESDAY, JUNE 23

8:30 to 10:30 a.m.—*General Session*
Presiding: L. F. Livingston, president

1 Meeting opened—E. M. Mervine, chairman, Local Committee
2 Address of Welcome—Dr. Chas. A. Lory, president, Colorado State College
3 President's Annual Address ("Agricultural Engineering Marches On")—Lawrence F. Livingston, manager, agricultural extension section, E. I. du Pont de Nemours & Co.
4 "The Common Interests of Agriculture and Industry"—Ralph E. Flanders, president, Jones and Lamson Machine Co.; past-president, American Society of Mechanical Engineers

10:30 a.m. to 12:30 p.m.—(Two concurrent joint sessions)

I—*Power and Machinery Division and Soil and Water Conservation Division*
Presiding: Frank. J. Zink and Virgil Overholt, respective division chairmen

SYMPOSIUM: "Correlation of Terrace Construction Practice and Farm Machine Design

II—*Farm Structures Division and Rural Electric Division*
Presiding: K. J. T. Ekblaw and I. P. Blauser, respective division chairmen

1 "Farm Lighting Recommendations"
2 "Dairy Ventilation"
3 "The Farm Wiring Problem"
4 "Structures Problems in Rural Resettlement"

2:00 to 4:00 p.m.—(Informal activities)
Committee and group conferences, trips, etc.

4:00 to 5:00 p.m.—Annual Business Meeting

8:00 to 10:00 p.m.—(Informal activities)

1 Two illustrated lectures (subjects to be selected)
2 Group round tables, recreation, etc.

WEDNESDAY, JUNE 24

8:30 to 10:30 a.m.—*General Session*
Presiding: L. F. Livingston, president

1 "What Hath Agricultural Engineering Wrought?"—Wheeler McMillen, editor, "The Country Home"
2 "Looking Ahead in Agricultural Engineering"—H. B. Walker, professor of agricultural engineering, University of California

10:30 a.m. to 12:30 p.m.—(Four concurrent sessions)

I—*Power and Machinery Division*
Presiding: Frank. J. Zink, division chairman

1 "Control of Weeds by Sulphuric Acid Sprays"
2 "New Development in Sugar Beet Machinery"
3 "Natural Drying of Farm Products"
4 "Possibilities for Farm Machinery Wheel Standardization"
5 "Problems of Wheel Standards for Rubber-Tired Farm Machines"
6 "Agricultural Wheel Standards for Pneumatic Tires"

II—*Rural Electric Division*
Presiding: I. P. Blauser, division chairman

1 "Cooperation in the Extension of Electric Service to Farms"
2 "Development of Electric Business in Rural Territories"
3 "Recent Developments in Rates and Rural Line Construction"

III—*Farm Structures Division*
Presiding: K. J. T. Ekblaw, division chairman

SYMPOSIUM: "Grain Storage on the Farm"

IV—*Soil and Water Conservation Division*
Presiding: Virgil Overholt, division chairman

1 "Effect of Buildings, Power, and Farm Improvements on Land Use"
2 "Are Present Laws Relating to Drainage Adequate?"
3 "Research Projects in Watershed and Hydrologic Studies"

2:00 to 5:00 p.m.—(Informal activities)
Committee and group conferences, trips, etc.

6:30 to 9:00 p.m.—*Annual ASAE Dinner*

THURSDAY, JUNE 25

9:00 a.m. to 12:00 a.m.—(Four concurrent sessions)

I—*Power and Machinery Division*
Presiding: O. E. Eggen, division vice-chairman

1 "New Developments in Fertilizer Placement Research"
2 "Engineering Phases of Pink Bollworm Control"
3 "Statistical Methods in Agricultural Engineering Research"
4 "Effect of Particle Size of Dusts in the Operation of Engine Air Cleaners"
5 "Developments in Offset Disk Harrows"
6 "Proposed Tractor Drawbar Standards"
7 "Problems in Farm Operation of Diesel Engines"
8 "Farm Tractor Fuels"
9 "Tractor Engine Lubrication under Low-Temperature Conditions"

II—*Rural Electric Division*
Presiding: Geo. A. Reitz, division vice-chairman

1 "Electricity in the Greenhouse"
2 "Present Status of the Electric Fence"
3 "New Developments in Electric Brooding"
4 "Dehydration of Farm Products"

III—*Farm Structures Division*
Presiding: A. M. Goodman, division vice-chairman

1 "Adobe Construction"
2 "Farm Building Costs and Valuations"
3 "Fire Insurance Rates for Rural Buildings"

IV—*Soil and Water Conservation Division*
Presiding: C. E. Ramser, division vice-chairman

1 "Soil Moisture Conservation"
2 "New Developments in Terracing in the Southeast"
3 "Engineering Developments on the Public Lands of New Mexico and Arizona"
4 "Engineering Problems in Erosion Control in California and Nevada"
5 "Soil Conservation Problems in Colorado"
(Two papers on irrigation—subjects to be announced)

ASAE Officers for 1936-37

As a result of the annual election of officers of the American Society of Agricultural Engineers just held, the new officers chosen to take office following the 30th annual meeting of the Society to be held at Estes Park, Colorado, June 22 to 25, are as follows:

President, RALPH UPSHAW BLASINGAME, professor of agricultural engineering and head of the department, Pennsylvania State College

First Vice-President, S. P. LYLE, senior agricultural engineer and extension specialist, Bureau of Agricultural Engineering, U. S. Department of Agriculture

Second Vice-President, A. W. TURNER, advertising department, International Harvester Company

Council, H. B. WALKER, professor of agricultural engineering and head of the department, University of California.

The Secretary of the Society, Raymond Olney, was reelected Treasurer.

The new Council of the Society for the year 1936-37 includes the above named officers, together with R. H. Driftmier and Q. C. Ayres, councilors; G. W. McCuen, senior past-president, and L. F. Livingston, junior past-president.

The newly elected Nominating Committee of the Society consists of J. B. Davidson (chairman), E. E. Brackett, and Wallace Ashby.

Washington News-Letter

According to the latest information from American Engineering Council, the "engineering embassy" at Washington, curtailment of the number of projects, of funds, and of staffs, occupy the attention of the heads of various federal departments and bureaus. This trend toward reducing government expenditures, while not yet large enough to affect materially the total budget, is in part brought about by the desire to decrease government expenditures and in part by the fact that over imaginative enterprises are being squeezed out of the final program of accomplishment in the facing of facts. Reform, and social objectives are still major factors, but economy and practicality are offsetting factors of increasing weight in determining government policy.

These trends are evident in several directions and the following inventory of legislation or executive action are typical:

Rural electrification now has a support of special legislation. The new act provides $42,000,000 a year for ten years for the construction of transmission lines into rural areas and the construction of generating plants where an adequate supply of electricity is not available, or where it cannot be obtained at what are thought to be reasonable prices.

Rural resettlement boils down to the following new projects actually in the work: Beltsville (or Berwyn) Maryland, sometimes called "Tugwell town"; the project in Cincinnati, Ohio; two projects in New Jersey, one at Bound Brook and one at Hightstown; and one in Champlain, Illinois. Two other projects are in the drawing board stage, one in Milwaukee, Wisconsin, the other, known colloquially as the "Dust Bowl" project, located in the area where Kansas, Oklahoma, Colorado, New Mexico, and Texas are contiguous states. In addition, earlier projects started under the FERA which have been picked to be finished are Cherry Lake, Florida; Red House, Charleston, West Virginia; Pine Mountain Valley Project, Warm Springs, Georgia; Mississippi County Project in Arkansas, and the Matanuska Valley Project in Alaska.

These projects however constitute the smallest part of the work of the Rural Resettlement Administration, there being two other major objectives; first, the purchase of submarginal land and second, rural rehabilitation. Seventy-three projects are underway for the purchase of submarginal land. Rural rehabilitation in the form of supervised credit for farm families on everything from seeds to a home is active.

The National Resources Committee, known originally as the National Planning Board, has been seeking legislation making possible the creation of a planned approach to the development of our natural, as well as human resources. The hearings held before the Land Policy Committee of the House were not friendly, perhaps because it is difficult to get congressmen to understand what is meant by "human resources." American Engineering Council has expressed itself as in sympathy with certain of the objectives of the National Resources Committee, particularly those objectives which seek to coordinate federal and state relations to such practical questions as water resources, flood control, coordinated development of mineral resources, etc. One simple objective recommended by Council's Committee on Water Resources, namely to set up a board of water resources, which would serve as a clearing house for factual information on this subject, has had the approval of the members of the National Resources Committee and of its subcommittee on Water Resources. Similarly, the proposal for a basic mapping program has had the approval of the Water Resources Committee. In brief, it would seem that it is possible to secure favorable consideration of a planned approach to the coordination of the orderly development of our "natural resources." When the world "natural" is supplanted by "national," and "human," as well as "material" resources are included, there apparently results a confusion of tongues.

Secretary Ickes has appointed Mr. John C. Page, acting commissioner of the Bureau of Reclamation. Mr. Page has been chief of the engineering division of the Bureau since October 1, 1935, when Dr. Mead transferred him from Boulder Dam to Washington. His age is fifty-nine. He is a graduate in civil engineering of Nebraska and Cornell and has been in reclamation since October 1, 1909. Mr. Page's appointment, while not yet confirmed by the Senate, fulfills the requirements set forth by President Potter in his letters to the President and to the Secretary of the Interior, urging that an engineer of experience be appointed and it is moreover, in line with Council's recommendations upholding the merit system in federal employment.

SAE to Hold Tractor Meeting

The Tractor and Industrial Power Equipment Committee of the Society of Automotive Engineers is sponsoring a meeting to be held April 15 and 16 at the Schroeder Hotel in Milwaukee, Wisconsin. Subjects to be presented in papers and discussions include "Tractors and Industrial Power Equipment in Highway Maintenance and Construction," "The SAE in Agricultural Power Engineering," "Looking Ahead with Engineers in the Agricultural Industry," "Automotive Ordinance and Mechanization," "Air-Cooled Radial Engine Performance Possibilities and Means for Obtaining Optimum Fuel Economy in Flight." "Tractor Engine Fuels—A Theoretical Analysis and Practical Test Results in the Laboratory and in the Field," "Diesel or Gasoline—Which Engine Will You Have?" and "Gasoline Versus Kerosene for Tractor Fuel."

A tour through the Waukesha Motor Company plant has been scheduled for the first afternoon. Engineers interested in the subjects scheduled are cordially invited to attend the meeting.

Second Annual Rural Electrification Course

R. U. BLASINGAME, head of the agricultural engineering department at the Pennsylvania State College, has announced that the department will offer a second annual rural electrification training course, April 22 to 24, inclusive. Cooperating with the college in putting on the course are the Pennsylvania Joint Committee on Rural Electrification, the Department of Public Instruction, Pennsylvania Electric Association, and manufacturers of electrically operated equipment.

Eighteen papers and several luncheon and dinner talks by men prominent in agriculture and rural electrification in the East are scheduled. The course is primarily intended to give utility company personnel a clear and definite understanding of proper application of electricity on farms.

Detailed information on the program and on registration can be obtained from the agricultural engineering department of Pennsylvania State College, State College, Penna.

Pacific N.W. Rural Electric Leaders Conference

FORTY-SIX rural electrification leaders attended a conference called by L. J. Smith, Hobart Beresford, D. B. Leonard, and F. E. Price (all ASAE members) at Walla Walla, Washington, March 3 and 4.

Feed grinding, portable motor uses, irrigation developments, farm refrigeration, drying, processing, farm-built electric lines, homemade farm electrical equipment, line extensions, electric hotbeds and soil sterilization, electric brooding, heating, and air conditioning of incubator and brooder rooms, new state wiring codes, and dealer cooperation in rural load building were subjects of papers and discussion.

Luncheon and dinner programs and an exhibit of homemade electrical appliances were features of the conference.

On Farm Chemurgic Program

THREE members of the American Society of Agricultural Engineers were on the program of a conference at Fresno, California, March 25 and 26, under the sponsorship of the Farm Chemurgic Council and The Chemical Foundation, for the purpose of advancing the industrial use of American farm products through applied science. They were Wheeler McMillen, editor of "Country Home," and Hobart Beresford and Harry Miller of the agricultural engineering staff of the University of Idaho.

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H. W. Riley, professor of agricultural engineering and head of the department, N. Y. State College of Agriculture, Cornell University, is one of the authors of Bulletin No. 339, entitled "How to Get Electricity on the Farm," recently issued by the Cornell Extension Service.

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He is survived by his widow and two small children; his parents, Mr. and Mrs. W. T. Raney of Meridian, Mississippi; two sisters, Mrs. C. B. Anders and Miss Ethel Raney of Meridian; and two brothers, Hiram Raney of Meridian, and Dr. Dan Raney of Matson, Mississippi.

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Agricultural Engineering Digest

A review of current literature by R. W. Trullinger, senior agricultural engineer, Office of Experiment Stations, U. S. Department of Agriculture.

The Relative Importance of Various Characteristics in Utensils Used on the Electric Range, *E. H. Roberts,* Jour. Home Econ., 27 (1935), No. 3, pp 174-178. This report from the Washington Experiment Station is summarized as follows:

"The relative effect of varied characteristics of cooking utensils has been studied, particularly with reference to the effect on the time required to boil water and on the thermal efficiency of the utensils on electric surface units. The characteristics which most markedly affected the time to boil water were the amount of water, the wattage of the unit, the contact with the unit, the bottom finish, and the cover of the utensil. Those affecting the thermal efficiency most decidedly were the amount of water, the contact with unit, the use of a cover to the pan, and the diameter of the pan in relation to the diameter of the unit. Thus, many of the variable characteristics affording maximum speed and efficiency in the heating process are seen to be external to the pan itself."

Alcohol and Alcohol-Gasoline Blends as Fuels for Automotive Engines: I, Performance Tests of Nearly Straight Alcohol of Different Grades Using a Six-Cylinder Engine, *A. L. Teodoro.* Philippine Agr., 24 (1935), No. 3, pp. 180-218, figs. 10. Studies conducted by the College of Agriculture of the University of the Philippines are reported in which 4 fuels were used with up-draft carburetors and 8 with down-draft carburetors.

The fuels used with up-draft carburetors included (1) an alcohol motor fuel consisting of alcohol 99, and gasoline 0.5, and aniline 0.5 per cent; (2) dehydrated alcohol consisting of alcohol 99, gasoline 0.5, and aniline 0.5 per cent: (3) a special motor fuel consisting of a mixture of 1 part of (2) to 1.21 parts of (1); and (4) gasoline. The fuels used with down-draft carburetors consisted of (1) alcohol motor fuel; (2) alcohol motor fuel consisting of a mixture of 2 parts of alcohol and 1 part dehydrated alcohol; (3) alcohol motor fuel consisting of 1 part dehydrated alcohol and 1 part alcohol; (4) blended fuel consisting of alcohol 60, gasoline 35, and benzol 5 per cent; (5) alcohol motor fuel consisting of 1 part dehydrated alcohol to 1.21 parts of alcohol; (6) alcohol motor fuel consisting of 1 part alcohol and 2 parts dehydrated alcohol; (7) dehydrated alcohol; and (8) gasoline.

With the up-draft carburetor it was found that the torque and consequently the brake horsepower developed at 2,000 rpm. was larger using alcohol motor fuel (1) than with the other fuels. The maximum torque for all fuels appeared at about 800 rpm. Fuel consumption of gasoline at three-fourths load was about 8 per cent lower than at full load. The results with alcohol fuels showed, however, that the lower the load the higher was the fuel consumption per brake horsepower hour. No difficulty was experienced in starting with alcohol fuels. There was evidence of slight detonation with gasoline at 2,000 rpm. on full throttle which was not observed with alcohol. The fuel economy using alcohol motor fuel (1) was reduced about 1.1 per cent when the jet was made large enough to develop the same power as gasoline. Engine operation was steadier with alcohol than with gasoline at or near full capacity. The reverse was true at low speeds and very light loads.

In general it was found that approximately the same maximum power was developed at 2,200 rpm, with all fuels used with down-draft carburetors, and the maximum torque appeared at about 1,400 rpm with all fuels except the blend. The larger the amount of gasoline present in the mixture the less was the fuel consumption per brake horsepower-hour.

It also was found that the lower the specific gravity of the alcohol fuels the less was the consumption per brake horsepower-hour. Alcohol fuels had a steadier operation when the mixture used was slightly rich than when lean. Preheating of alcohol fuels when down-draft carburetors were used showed that full preheating shortened the time of warming the engine and decreased the maximum power at higher speeds. Carbon deposit studies showed the largest deposits to be on cylinder heads and piston heads, and that spark plugs had only traces of carbon when alcohol fuel was used. Alcohol fuel produced less carbon than gasoline. No dilution of the crank case oil was found with alcohol fuels. After 10 hrs. of continuous operation the crank case oil became thicker than the original, this thickening being greatest in the test using dehydrated alcohol. The average ring wear for all cylinders was largest for dehydrated alcohol and smallest for alcohol motor fuel (1).

Alcohol and Alcohol-Gasoline Blends as Fuels for Automotive Engines: II. Performance Tests of Nearly Straight Alcohol of Different Grades Using a Four-Cylinder and an Eight-Cylinder Automobile Engine, *A. L. Teodoro.* Philippine Agr., 24 (1935), No. 4. pp. 296-325, figs. 14. This is the second contribution to the subject from the College of Agriculture of the University of the Philippines.

Studies were made the primary purpose of which was to compare alcohol motor fuel, dehydrated alcohol, and gasoline in engines operated with and without preheating under variable speeds and loads at low and high compression.

Tests under low compression showed that higher power was developed with no preheating than with preheating and that the peaks of the torque curves for all fuels appeared between 1,200 and 1,400 rpm. Beyond 1,300 rpm the operation of the engine at higher loads was steadier with alcohol motor fuel than with either dehydrated alcohol or gasoline, especially when the jets used were large enough to admit a slightly rich mixture. The maximum fuel economy was at about 1,500 rpm.

Tests under high compression showed that although it was possible to start the engine on gasoline, it would not carry any load, and that with a fixed carburetor setting greater power was developed without preheating than with preheating. The peak of the torque curves appeared at about 1,400 rpm, and the most economical point was at about 1,700 rpm.

It was found further that total ring wear with alcohol fuels using crankcase oil without any upper cylinder lubricant was more than three times the wear using crankcase oil and upper cylinder lubricant.

Approximately 12 per cent more carbon accumulated with alcohol motor fuel when using crankcase oil without upper lubricant than when using crankcase oil with upper lubricant. The total carbon deposit was about 17 per cent greater for gasoline than for alcohol motor fuel and about 14 per cent greater than for dehydrated alcohol.

Tests of these fuels under different speeds and loads showed that the maximum torque between the speeds of about 800 and 1,800 rpm was higher with alcohol fuels than with gasoline by about 2 ft-lb. Beyond 1,800 rpm the torque of alcohol motor fuel was highest and that of dehydrated alcohol lowest. It was found possible to give the engine a pick-up with alcohol fuels equally as good as with gasoline by keeping the alcohol mixture a little rich.

The Agriculture Situation in the Irrigation States, July 1, 1935. U. S. Dept. Agr., Bur. Agr. Engin. (1935), pp. 15. The mimeographed report describes agricultural conditions in the irrigation states as they stood on or about July 1, 1935, with particular reference to water supply.

Salinity of Irrigation Water and Injury to Crop Plants, *F. M. Eaton.* Calif. Citrogr., 20 (935), nos. 10, pp. 302, 322, 324, 326, fig. 1: 11, pp. 334, 362-365, figs. 5. In a contribution from the USDA Bureau of Plant Industry, data are summarized on salt accumulations in irrigation water and the mechanism of injury to crop plants. This information is essential in connection with the drainage of irrigated lands.

Electricty on the Farm, Compiled by *D. W. Graf,* U. S. Dept. Agr., Bur. Agr. Engin. 1935, pp. 20 + 110. This is a partial mimeographed list of references with an author index.

Housing the Rural Worker: Progress of Reconditioning in Devon, *R. T. Shears.* Jour. Min. Agr. (Gt. Brit.), 42 (1935), no. 6, pp. 542-550, pls. 8. The progress of reconditioning of rural dwellings in Devon County, England, is summarized, with particular reference to costs and financing and methods of reconditioning employed. A few reconditioned dwelling are illustrated.

(Continued on page 180)

Agricultural Engineering Digest

(Continued from page 172)

RECENT DEVELOPMENTS IN THE UTILIZATION OF SOYBEAN OIL IN PAINT, *W. L. Burlison.* Illinois Sta. Circ. 438 (1935), pp. 8, fig. 1. This is an address delivered at the annual meeting of the American Soybean Association, Evansville and LaFayette, Ind., August 21-23, 1935, in which investigations conducted at the station are briefly described.

In these studies paints were tested in which soybean oil constituted varying proportions up to 50 per cent of the total vehicle (liquids) used in the paint. Direct comparisons were made with standard linseed oil paints.

The first test panel exposures were made during the spring of 1931 when a large number of panels were put out. The purpose was to study, first, the behavior of paints differing primarily in their content of raw and treated soybean oil, and, in addition, to compare the effectiveness of different driers.

After the panels had been exposed for 2 yr on the rack (set at a 45-degree angle), it was evident that the type of exposure was exceedingly severe. It was an accelerated test which was probably twice as rapid in getting results as the side of a building or panels exposed upright would have been. It was clear also that the pigment has much to do with the durability of the paints, as might be expected.

Interior paints, as well as exterior ones, were studied. The first of the panels coated with interior paints containing soybean oil were put up in the spring of 1931.

From the exposure and other tests which have been made, the conclusion is drawn that soybean oil has a permanent place in the manufacture of paint. The results on the panels were found to support the findings of other workers to the effect that 30 per cent and more of the oil used in the paint can be made up of soybean oil when properly treated and when driers suited to this kind of oil are used.

TRACTIVE EFFICIENCY OF THE FARM TRACTOR, *J. B. Davidson, E. V. Collins,* and *E. G. McKibben.* Iowa Sta. Res. Bul. 189 (1935), pp. 258-333, figs. 95. This publication treats specifically the application of tractor power to a towed machine or to a load pulled by a drawbar, but farm power is treated briefly in a broad way to establish relationships. The investigational work reported has been directed toward the determination of tractive efficiency, or the ratio between power delivered for useful work at the tractor drawbar and power developed by a mechanical motor under the influence of such variable factors as traction equipment (steel wheels, pneumatic tires, tracks, etc.), weight, height of hitch, and traction surface. In the tests reported the power was measured as it was delivered to the traction members, and the input so obtained was not actually the power supplied by the motor.

Concerning steel tractor wheels, the rolling resistance of tractors over the tractive surfaces was the principal cause for low efficiency. Lugs or grouters of excessive length used to increase adhesion on a firm surface or turf may cause considerable loss in efficiency. With a wheel tractor weighing 5,620 lb, the power required to overcome rolling resistance at a speed of 3 miles per hour varied from 2.45 hp with drivewheels without lugs to 6.3 hp. with drivewheels equipped with 4-in spade lugs. Because of the lugs, rolling resistance on oats stubble did not differ greatly from that on freshly plowed land.

On a loose soil of uniform texture, an increase in length of spade lugs from 4 to 7 in increasingly lowered tractive efficiency, and on the same soil an increase in the width of the tire by use of an extension rim gave higher tractive efficiency. On soil with a loose surface but firm subsurface, a spade lug 9 in long, reaching firm soil, resulted in a slightly increased efficiency over 6- and 7-in lugs, but was less than for 4- and 5-in lugs.

Five-inch angle lugs mounted on a wheel 42 in in diameter with a rim 12 in wide gave higher tractive efficiency than spade lugs on freshly prepared loose soil. Extension angle iron lugs increased tractive efficiency on loose soil materially, about one-fifth to one-fourth. Angle iron lugs extending over wheel rims were advantageous on sticky soil, because the soil did not pack in between the lugs. Increasing the weight from 1,750 to 2,250 lb on a 12 by 42-in traction wheel equipped with spade lugs increased the drawbar pull 75 to 100 lb at maximum efficiency. The drawbar pull was increased approximately 200 lb when the wheel was equipped with extension rims and angle lugs. Angle iron lugs gave slightly better results with a 6-in rim extension than without on freshly prepared loose soil. Open-type traction wheels performed practically the same as 12-in rim wheels with lugs on firm traction surfaces of cinders or sod. The rim did not function, as the weight was carried entirely on the lugs. On loose, freshly prepared soil where the space between the lugs did not fill with soil, the rim wheel gave slightly higher tractive efficiency than open wheels. The tractive efficiency of steel drivewheels was progressively raised by increasing the diameter from 38 to 58 in by 4-in increments. The effect of wheel diameter is more marked on less firm traction surfaces.

The rolling resistance of a wheel tractor, defined herewith as drawbar pull, or its equivalent, required to move the tractor over a given surface, was materially reduced by low-pressure pneumatic tires for all conditions observed. On a smooth hard surface the maximum tractive efficiency of a tractor equipped with pneumatic tires was 84 per cent. The maximum drawbar pull of a tractor equipped with low-pressure pneumatic tires was materially reduced on stubble and loose soil, and the same can be increased by additional weight, chains, or lugs. The maximum tractive efficiency was increased progressively with a decrease of inflation pressure from 20 to 16, 12, and 8 lb per square inch.

The tractive efficiency of a track tractor as observed is not materially influenced by normal variations of traction surfaces. On freshly prepared loose soil, maximum tractive efficiency of a track was lowered by increasing the height of hitch.

THE FLOW OF WATER IN PIPES, SEWERS, AND CHANNELS, OVER WEIRS AND OFF CATCHMENTS, *G. B. Williams.* Chapman & Hall (London), 1934, pp. 76 (figs. 48). This reference book contains velocity formulas for sewers, pipes, and channels; data on velocities and discharges in sewers, pipes, and channels; discharge diagrams for weirs and notches; and data relating to catchments.

BIBLIOGRAPHY ON NEW BUILDING MATERIALS, compiled by *D. W. Graf.* U. S. Dept. Agr., Bur. Agr. Engin., 1935, pp. 9.

BIBLIOGRAPHY ON RURAL WATER SUPPLY, compiled by *D. W. Graf.* U. S. Dept. Agr., Bur. Agr. Engin., pp. 24.

RAMMED EARTH IN BUILDING CONSTRUCTION, *R. L. Patty.* S. Dak. Acad. Sci. Proc., 14 (1928-29, 1931-34), pp. 61-68. A summary is given of the progress of studies at the South Dakota Experiment Station on the use of rammed earth for building structures, particularly those used in agricultural production.

BIBLIOGRAPHY ON STONE HOUSES, 1920-1934, compiled by *D. W. Graf.* U. S. Dept. Agr., Bur. Agr. Engin., 1935, pp. 4.

ANTIKNOCK EFFECT OF TETRAETHYLLEAD, *J. M. Campbell, F. K. Signaigo, W. G. Lovell,* and *T. A. Boyd.* Indus. and Engin. Chem., 27 (1935), no. 5, pp. 593-597, figs. 6. Quantitative measurements of the specific antiknock effect of tetraethyl lead in 62 individual hydrocarbons were made by finding the increase in critical compression ratio in a single-cylinder, variable-compression engine made possible by the addition of tetraethyl lead in a concentration of 1 cc per gallon. Upon this basis there are as many as 20-fold variations in the effectiveness of tetraethyl lead in suppressing knock in different hydrocarbons. Certain general relationships between hydrocarbon structure and susceptibility to lead, which appear to be consistent within the scope of this work, are described.

The data on the effect of tetraethyl lead concentration on the critical compression ratios of a few hydrocarbons show that tetraethyl lead is usually most effective at low concentrations. This characteristic appears, in general, to be most pronounced in the compounds in which the tetraethyl lead is the most effective, and applies to both anti-knock and knock-inducing action. It appears that tetraethyl lead exhibits a very wide range of effectiveness in changing the critical compression ratio of pure hydrocarbons, depending upon the structure and properties of the hydrocarbon. In general, the compounds in which lead is more effective appear as those which have a double bond removed from the end of the molecule. As the double bond is progressively moved towards the center of the molecule, the effectiveness of lead in the compound increases. The opposite condition seems to prevail for the acetylene compounds, however, and this relationship appears somewhat similar to that observed for the critical compression ratios of these same hydrocarbons. In the case of the oelfins with the double bond next to the terminal carbon atom or in the alpha position, the lower members of the series are compounds in which lead is more effective when the measurements are made with the pure compounds.

A METHOD OF DETERMINING THE FLOW-NET IN SOIL SEEPAGE, *M. G. Ionides.* Engineering (London), 140 (1935), no. 3633, pp. 211, 212, figs. 5. A methodology and apparatus for presenting an exact representation of the flow lines in soil seepage are briefly described. The apparatus is primarily suitable for structures subject to small head.

(Continued on page 182)

Anyone Can Operate the
HESSELMAN OIL ENGINE
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Burning modern Diesel fuels, yet so simple in construction that anyone who understands a gasoline engine can operate it . . . that's the Waukesha-Hesselman Oil Engine.

Like a gasoline engine it starts easily and promptly . . . may be hand cranked . . . and needs no lengthy warm-up period. It is *not* a semi-Diesel. It has no hot bulb or hot spot requiring preliminary heating.

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WAUKESHA MOTOR COMPANY
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Agricultural Engineering Digest

(Continued from page 180)

ALCOHOL AND ALCOHOL-GASOLINE BLENDS AS FUELS FOR AUTOMOTIVE ENGINES: III. PERFORMANCE TESTS OF ALCOHOL, GASOLINE, AND ALCOHOL-GASOLINE MIXTURES AS FUELS FOR AN EIGHT CYLINDER AUTOMOBILE ENGINE, *A. L. Teodoro*. Philippine Agr., 24 (1935), No. 5. pp. 352-387. figs. 18. This is the third contribution to the subject from the College of Agriculture of the University of the Philippines.

The purpose of the study is to determine the performance of an 8-cylinder engine when gasoline, alcohol, and alcohol-gasoline mixtures are used as fuels. The important points considered were operating characteristics and fuel economy.

Two groups of tests were carried out. In the first group 11 series of bench studies were made on 11 different kinds of fuels. In the second group 7 series of road tests were conducted. Denatured alcohol 193° proof was used in the fuel mixtures containing from 10 to 50 per cent alcohol. From 50 per cent up, a grade containing only 190° proof alcohol was utilized.

The engine used showed a very satisfactory performance when alcohol, gasoline, and alcohol-gasoline combinations were used as fuels. A mixture containing 5 per cent 193° proof denatured alcohol was found miscible with gasoline as low as 21° C. The engine adjustment best suited for gasoline was found ideal for operation on mixtures containing as high as 15 per cent alcohol. To obtain a very satisfactory performance, a part choking of the carburetor was needed for mixtures containing 20 per cent alcohol. To produce the same power as gasoline without changing the size of the venturi tube or of the air passage area, jets larger than the one adapted for gasoline were used for mixtures containing at least 15 per cent alcohol.

At speeds below 500 rpm, very economical adjustments with mixtures containing at least 20 per cent alcohol were often characterized by jerky and uneven operations. Engine detonation was much in evidence using gasoline at full throttle. Pinking was minimized as the percentage of alcohol in the mixture was increased. No sign of detonation was noted at any load and speed when the mixture used contained at least 20 per cent alcohol. In general, constancy in operation at higher loads could be maintained for a longer time with the mixtures than with gasoline. If desired, greater maximum power could be developed with mixtures than with straight gasoline. This is true especially for mixtures containing a large amount of alcohol. As the percentage of alcohol in the mixture was increased, the engine pick-up was slightly slowed down. Engine starting with almost straight alcohol was not always very easy when the engine was cold.

In general it was observed that at full load and at some points in three-fourths load the mixtures containing as high as 20 per cent alcohol were more economical than gasoline, and at other loads the larger the percentage of alcohol in the mixtures the higher was the fuel consumption per brake horsepower-hour. The increases varied from an average of 4 to 6 per cent for every 10 per cent of alcohol added. The mixture containing the least amount of gasoline had the highest efficiency. At full load, gasoline had the lowest efficiency on all speeds. A mixture containing 10 per cent alcohol gave greater mileage than gasoline under the conditions in which they were tested.

PROPERTIES OF LUBRICATING OILS, *A. P. Henry*. S. Dak. Acad. Sci. Proc., 14 (1928-29, 1931-34), pp. 45-48. This paper reports studies conducted at South Dakota State College of the relationship between viscosity of lubricating oils and the dilution of oils with gasoline in internal-combustion engines.

A comparison of new and used oils showed a difference of 265 degrees F in flash point, which indicates that the gasoline was evidently present in the oil in a fairly large quantity. The fire point of the new oil was 475 degrees and of the used oil 470 degrees, a difference of only 5 degrees.

In testing the viscosity, the approved Saybolt viscosimeter was used. The viscosity at 70 degrees showed the greatest difference; the Saybolt number of the new oil was 1929.2, while the used oil number was 862, less than half as much. This indicates about a 5 per cent dilution.

At 130 degrees the Saybolt number of the new oil was 215.6 and the used oil number was 153.4, which is considerably more than one-half the new oil number. At 210 degrees the results approach each other more closely, since the unused oil number is 58.4 and the used oil number is 53.2.

In the tests showing the relation between viscosity and dilution of oils, it was found that when the mixture contains one part in 16 of gasoline, the viscosity is less than half what it is when the sample is pure oil.

REINFORCED BRICKWORK, *H. D. Williamson*. Rensselaer Polytech. Inst., Engin. and Sci. Ser. no. 46 (1934), pp. 44, figs. 16. The results of a series of tests are reported the purpose of which was to determine what effect the brick themselves may have upon the strength and behavior of reinforced brick structures.

In that connection physical studies of the brick included (1) compression tests with brick flatwise, edgewise, and endwise, (2) modulus of rupture tests with brick flatwise and edgewise, and (3) absorption tests in cold water up to 48 hr and in boiling water for 5 hr.. For purposes of design, the elements investigated were (1) the bond between the reinforcing steel and the mortar and (2) the bond between brick and mortar in both tension and shear. Supplementing these tests, small beams were constructed with each series of brick and tested for strength and deformation in order to compare the results from the mortar bond tests and those obtained at larger demonstration structures tested at various brick plants throughout the country.

It was found that there is no direct relation between any of the common physical tests of the brick. Many common brick absorb the major portion of their capacity during the first few minutes of cold immersion.

Surface features of the brick are important where strength of bond is desired. Brick plant dust practically destroys bond strength. The bond strengths of brick may be better indicated in the bond tension test than in the bond shear test, for the reason that in the bond shear test with rough surface brick a wedging action occurs. The rate of absorption of brick, either in the first few minutes or during the initial set period of the mortar, is an index for the bond strengths, the lower rates indicating the higher values.

Reinforced brickwork may be designed using the straight-line theory of flexure provided the bond tension, bond shear strengths, and the stress-strain ratio of the brickwork are properly considered. The time required to lay reinforced brick masonry is about the same as that for ordinary masonry of good quality.

No danger from loose brick will result if all mortar joints are carefully constructed. Flat bed joints should be used. Head joints should be full. The importance of exerting a pressure on each joint as the brick are laid should not be overlooked.

REPORT OF THE COMMITTEE ON THE MECHANICAL TESTING OF TIMBER, *J. A. Ewing et al.* Dept. Sci. and Indus. Res. (London), 1934, pp. VI + 41, figs. 25. The report of the committee relates to the various mechanical tests in common use. A detailed and extensive set of conclusions as to efficiency of the various tests includes also suggestions on improvements. The more important tests considered are tension along the grain, tension perpendicular to the grain, compression along the grain, compression perpendicular to the grain, shearing along the grain, static bending, impact bending, hardness, abrasion, and notched bar impact.

BIBLIOGRAPHY ON FIREPLACES, 1900-1934, compiled by *D. W Graf*. U. S. Dept. Agr., Bur. Agr. Engin., 1935, pp. 16.

CALCULATED NET INCOME RESULTING FROM LEVEL TERRACES ON RICHFIELD SILT LOAM SOIL AND SUGGESTED LINES OF DEFENSE AGAINST WIND EROSION, *H. A. Daniel*. Oklahoma Panhandle Sta., Panhandle Bul. 58 (1935), pp. 14, figs. 2. A summary and analysis of data from terraced fields is presented.

Grain yields from terraced and unterraced plats were secured on Richfield silt loam soil from 1926 to 1935, inclusive, at Goodwell, Okla. The terraced land yielded 31.08 bu more per acre than the adjacent unterraced land, or an average of 3.1 bu. annually.

Terraces placed about 35 ft apart on land with about 1 per cent slope were found to be more efficient from a crop-production standpoint. These terraces increased the crop yield 286.9 lb per acre over the unterraced land during the last 6 yr. The plats with terraces about 70 ft apart made an average gain of 102.8 lb per acre, and the land with terraces about 140 ft apart made an average gain of 99 lb per acre.

The average cost per acre for building broadbase terraces, not including labor, was 77 cents. The extra cost of cultivating terraced and contoured land was estimated to vary from 20 to 50 cents per acre annually.

The total calculated increase in income due to terracing over the adjacent unterraced land was $23.33 per acre for the last 10 yr. The total expense of building the terraces and cultivating on the contour was estimated at $5.77 per acre. After deducting the total expenditure from the total income, the calculated net income was found to be $17.56 per acre, or an average annual cash income of $1.75 per acre.

Suggested lines of defense against wind erosion are also discussed.

A list of fourteen references to work bearing on the subject is included.

Heating Liquid Culture Media

(Continued from page 142)

Judging from the yield obtained from the plants which had room to grow without being cramped, it appears probable that one ton of tomatoes could be grown in twelve months on 100 square feet of basin area if there is ample room for upward development.

4 The electrical equipment used to heat the solution was more than adequate to maintain the desired temperatures under the conditions of the experiment. In heating the solution a uniform temperature is maintained over the entire root system and no temperature gradient is developed as in heating soil.

5 The electrical energy required to heat the solution could have been materially reduced by insulating the sides and bottom of the basins and by covering the top with a thicker layer of excelsior and sawdust. Further experimental work is necessary to determine the best type of basins and the value of insulating them.

The investigations on the heating of nutrient culture media for plant growth concerned both engineering and plant-physiology problems. The results obtained from the first effort of using heated-liquid media for forcing have been so encouraging that it appears safe to assume the method can be perfected for greenhouse culture; in fact, some commercial enterprises are already using the method. These commercial enterprises, however, are yet experiments; for they require the attention of both engineer and plant physiologist for the solution of problems not envisioned in the original experiments.

Aerial Surveying for Measuring Fields

(Continued from page 165)

from this table by the area scaled from the enlargement with a planimeter adjusted to read in square inches.

Index System. The problem of indexing and filing the 450 enlargements for protection and efficient use required careful attention. Skeleton township maps were prepared showing section lines, outline of each farm, name of owner and total deeded acreage. Section lines were drawn on the enlargements and each section numbered, e.g., 9-2-24 indicating Township 9 North, Range 2 East, Section 24. The farms were then numbered by sections, and the fields on each farm. Thus the complete number to denote Field 2 on Farm 7 of Section 24, Range 2 East, and Township 9 North would read 9-2-24-7-2. The enlargements were numbered and filed in numerical order. A card index was made up, containing a card for each farm showing pertinent information, and filed according to farm number.

The use of aerial photographs has several distinct advantages over the field traverse method besides those apparent in the above description. One is that the prints show all fields and all farms instead of only the commodity fields which were under contract and therefore had to be measured. Thus the first costs are saved on any new fields that it may become necessary to measure. Also the actual measurement of areas becomes an office job and thus lends itself to a more rigid control of errors than was possible with a large temporary force of inexperienced field men working on different farms over the county. It is evident that many other important uses for these maps will be found by private and public organizations. The complete significance of this additional value cannot yet be estimated.

It is interesting to note that these valuable maps were produced by one county and made to show a saving in cost when used only for the measurement of commodity crops. Considering the fact that this was accomplished in a first attempt which is subject to numerous improvements to increase efficiency, the use of aerial photography in solving this and other similar surveying problems, seems destined for a much wider adoption.

Light and Its Effects on Plant Growth

(Continued from page 152)

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EMPLOYMENT BULLETIN

The American Society of Agricultural Engineers conducts an employment service especially for the benefit of its members. Only Society members in good standing may insert notices under "Positions Wanted." or apply for positions under "Positions Open." Both non-members and members seeking to fill positions, for which ASAE members are qualified, are privileged to insert notices under "Positions Open," and to be referred to members listed under "Positions Wanted." Any notice in this bulletin will be inserted once and will thereafter be discontinued, unless additional insertions are requested. There is no charge for notices published in this bulletin. Requests for insertions should be addressed to ASAE, St. Joseph, Michigan.

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AGRICULTURAL ENGINEER, graduate of Kansas State College, desires employment where his training and experience will fill a need. Farm background, and experience in concrete work and soil erosion control. Age 25. Single and free to travel. PW-269

AGRICULTURAL ENGINEER looking for work on broader scope. Born and reared on farm. Have agricultural degree and equivalent training and experience in electrical engineering; three years farm management; twelve years in rural electrification and associated work. Minimum salary $2,600. PW-270

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ENGINEER (preferably agricultural) is offered considerable block of non-assessable stock in a close corporation which controls through strong patents, etc., the manufacture and sale of practical concrete construction specialties of proved utility. This stock can be paid for by development work that need not interfere with the engineer's usual activities. To an ambitious engineer having executive ability, this offers an opportunity to become a high official of a corporation that in due time should become a strong, nationally known firm. PO-112